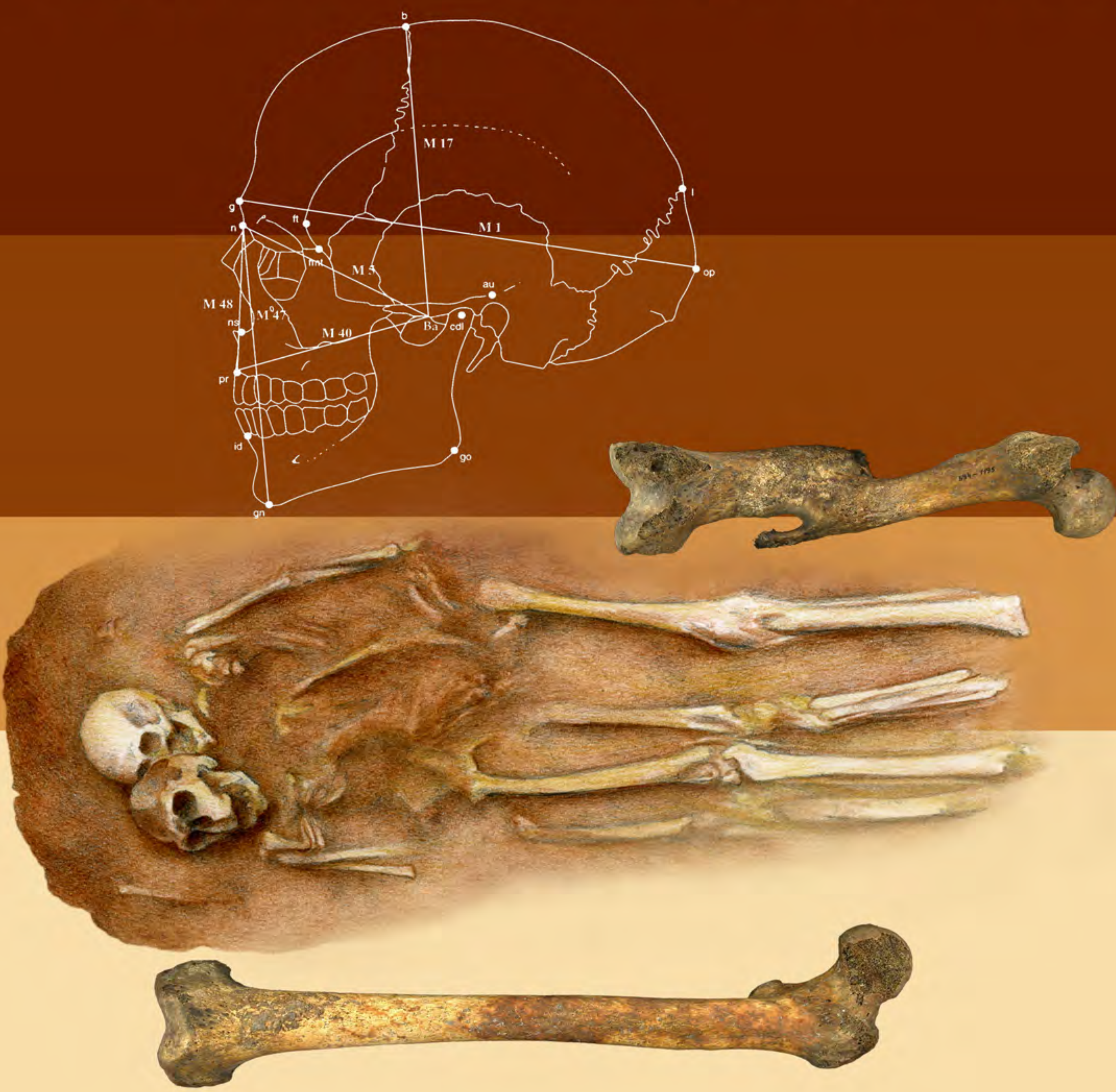
STUDIEN ZUM BURGWALL VON MIKULCICE VIII



Petr Velemínský – Lumír Poláček
(Hrsg.)

Studien zum Burgwall von Mikulčice VIII

SPISY ARCHEOLOGICKÉHO ÚSTAVU AV ČR BRNO
27

Studien zum Burgwall von Mikulčice

herausgegeben von
Felix Biermann – Pavel Kouřil – Lumír Poláček

ARCHEOLOGICKÝ ÚSTAV
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BRNO 2008

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Foreword

The eighth volume of „Studien zum Burgwall von Mikulčice“, as its subtitle – „Anthropological and epidemiological characterization of Great-Moravian population in connection with the social and economic structure“ – suggests, is dedicated to the biological properties of the Great Moravian population in relation to the social structure of this society. Great Moravia represents the first state formation of the Slavs, whose centre in the 9th century AD occupied the region of Moravia (part of the Czech Republic), west Slovakia and nord part of Lower Austria.

The project whose results we present here was launched in 1999, when we could still refer to the Great Moravian population as people from the past millennium. It represents a continuation of several decades of anthropological research of the Great Moravian burial sites, especially those at Mikulčice. Research associated with the names of Milan Stloukal and his colleagues, Hana Hanáková and Luboš Vyhnánek. It is natural that some of the authors of this volume are members of the Anthropological Department of the National Museum, just like their predecessors. The biological study of the inhabitants of Great Moravia is a “tradition” and one of the key points of interest of this department. Cooperation with the Mikulčice base of The Institute of Archaeology of the Academy of Science in Brno dates to the department’s foundation, i.e. the late 1960s or rather the late 1950s, as personified by Milan Stloukal.

Besides the two institutions mentioned above, the Department of Anthropology of the National Museum (Petr Velemínský, Miluše Dobisíková, Petra Havelková, Marek Jantač) and the Institute of Archaeology of the Czech Academy of Science in Brno (Lumír Poláček), another ten institutions collaborated on this volume. These institutions mainly included the Department of the Archaeology of Landscape and Archaeobiology, the Institute of Archaeology of the Academy of Science in Prague (Petra Stránská, Jakub Likovský, Markéta Urbanová, Martin Hájek, Viktor Černý), the Department of Anthropology of the Faculty of Science, Charles University Prague (Jana Velemínská, Martina Kujanová, Lucie Bigoni, Kristina Krchová), Laboratoire d’Anthropologie des Populations du Passé (LAPP), University of Bordeaux, France, the Department of Anthropology, Faculty of Humanities, University of West Bohemia, Plzeň (Jaroslav Brůžek), the Institute of Dental Research, General Teaching Hospital Prague (Pavel Trefný), the Institute of History of Medicine and Foreign Languages, Charles University Prague, the 1st Faculty of Medicine in Prague (Václav Smrčka), 3rd Department of Internal Medicine, 1st Faculty of Medicine, Charles University, Prague (Vít Zikán), the Czech Geological Survey, Prague (František Bůzek), the Institute of Geochemistry, Faculty of Science, Charles University, Prague (Martin Mihaljevič), the Institute of Applied Mathematics and Information Technologies, Faculty of Science, Charles University, Prague (Jarmila Zocová).

This volume contains sixteen papers that may be divided into several areas of interest. An introduction of the historical and archaeological issues of Great Moravia and a presentation of the power centre at Mikulčice is followed by the biological section itself. The first papers are devoted to palaeodemographic issues and presents a proposal for secondary sexual diagnosis based on the skull dimensions of the Mikulčice population and the comparison of genetic and morphological sex determination of sub-adult individuals. This is followed by a study of the stature and the morphology/structure of the facial part of the skull, i.e. work devoted to the physical appearance of the inhabitants of Great Moravia. Most of the papers then represent studies and articles attesting to the health status of the Great Moravian population. A number of these deal with traits that may be interpreted as possible manifestations of non-specific stress, of either physiological-metabolic or physical character. Two papers relate to dentition; apart from the evaluation of the state of dentition itself, they deal with the issue of hypoplastic enamel defects. Several studies focus on the structure and state of health of the locomotor apparatus. In the case of the long bones of the upper and lower extremities, the asymmetry of their structure, the incidence of Harris lines and the frequency of fractures were evaluated. In the case of the femur, the extent of osteoporotic changes was studied with the aid of Dual-Energy X-ray Absorptiometry. Other articles are linked by the theme of the quality of diet of the Great Moravian population. One evaluation used the isotopes of carbon and nitrogen, while another used selected trace elements. Finally, the last three papers deal with the application of non-metric morphological traits in the comparison of socially different population groups. The common denominator of all these papers is the population-based, not casuistic-based, evaluation of biological traits, always taking into consideration the socio-economic structure of the given society. More precisely, based on relevant biological indicators, three socio-economically different areas of the Mikulčice agglomeration or the corresponding population groups are compared: 1/ the inhabitants of the castle buried at the sites next to the IInd and IIIrd church; 2/ the people buried in the sub-castle (suburb), at Kostelisko and 3/ the population group living/buried in the hinterland of Mikulčice centre, at Josefov and at the Prušánky site.

The papers are conceived as autonomous, independent articles, which is why basic information relating to the burial sites is repeated at times.

The aforementioned studies represent the first compilation of the conclusions of research into the biological indicators of the inhabitants of Great Moravia, which to various degrees attest to their appearance and state of health, and indirectly to the quality of their living conditions. Among the traits that could not be included in this volume in view of this publication's extent but that were evaluated, we find e.g. the degenerative changes of articular junctures on the vertebral column and appendicular joints, the changes in the region of muscle/ligament attachments (enthesopathies), the lateral flattening of the bodies of long bones, the cribra orbitalia or hyperostosis porotica.

Apart from the authors, other collaborators and institutions participated on this publication. This book is published by the Institute of Archaeology of the Czech Academy of Science, Brno in cooperation with the National Museum in Prague. Publication of the book is financially supported by the Grant Agency of the Czech Republic (GA ČR 206/03/0725), the Czech Ministry of Culture (VZ PM MK00002327201) and the research plan of the Institute of Archaeology of the Czech Academy of Science, Brno, No. AV0Z80010507. We would also like to thank Mrs. Marie Cimflová for her editorial revisions and for technically preparing this volume for printing. We also thank Academic Painter Pavel Dvorský for the graphic design of the book cover. We thank Presto Prague for translation and revision of the English text. We thank the employees of the Department of Anthropology of the National Museum in Prague for the documentation and technical work (Táňa Dubová, Hana Horáková, Jitka Vítková, Alena Klímová) and the base of the Institute of Archaeology of the Czech Academy of Science at Mikulčice (Otto Marek, Rostislav Skopal). Of course, we thank to both reviewers, Milan Stloukal and Milan Thurzo, for valuable suggestions nad corrections.

Lumír Poláček – Petr Velemínský

Anthropological and epidemiological characterization of Great-Moravian population in connection with the social and economic structure

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Anthropological and epidemiological characterization of Great-Moravian population in connection with the social and economic structure

Great Moravia, the Power Centre at Mikulčice and the Issue of the Socio-economic Structure

Lumír Poláček[1]

Great Moravia existed in the 9th century AD in the region north of the Middle Danube. It was the first state formation of the Slavs. Its political legacy – the model of a Christian state relying on its sovereignty an archbishopric directly subordinate to the pope – was taken up by the later Early Middle Ages states of Central Europe. The stronghold of Valy near Mikulčice was a prominent centre of this state formation and at least temporarily the residence of the ruling Mojmír dynasty. This was an island stronghold located in the flood plain of the Morava River, which merged the attributes of a military fortress with those of an early urban formation. The concentration of churches and other walled 9th century structures in Mikulčice has no analogy far and wide. Archaeological research at Mikulčice has been going on for over fifty years now, conducted by the Mikulčice base of the Institute of Archaeology of the Czech Academy of Science in Brno. This research has provided an enormous amount of source material, which is currently being processed and analysed. It includes material from 2500 graves explored at Mikulčice as well as other thousands of graves uncovered in the stronghold hinterland. From an archaeological aspect, this represents a very valuable material for the study of the socio-economic structure of the centre and its hinterland. From an anthropological aspect, the grave material represents an inexhaustible source of information and knowledge relating to the population of the time. Processing of the human skeletal remains has been traditionally conducted by the Department of Anthropology of the National Museum in Prague, partly in the form of common projects with the Institute of Archaeology of the Czech Academy of Science in Brno.

Key words: Great Moravia – Mikulčice – archaeology – anthropology – socio-economic structure

1. Great Moravia

1.1 Great Moravia in the history of Central Europe

Great Moravia was the first Slavic state formation. It left behind a significant political and cultural legacy, taken up later on by the Early Middle Ages states of Central Europe – Bohemia, Poland and Hungary. This legacy was mainly represented by the model of a Christian state whose international recognition and legitimacy were based upon an archbishopric directly subordinate to the pope. Politically and culturally, Great Moravia stood on the boundary between the spheres of Byzantium, Rome and the Frankish empire. Although Eastern Christian learning associated with the activities of the Byzantine mission did not become permanently rooted in Moravia, it did fundamentally affect further cultural development of the Southern and Eastern Slavs. A distinct and original material culture is what today defines most significantly the cultural domain of Great Moravia. Its character is well known from the results of extensive archaeological excavations especially that, conducted in the second half of the 20th century.[2]

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2 For the position of Great Moravia in the history of the Central Europe see e.g. Havlík 1985 and Třeštík

1.2 The territorial and political development of Great Moravia

Two entities lay at the core of the Great Moravian state formation – Old Moravia on both shores of the Morava River and the principality of Nitra in south-western Slovakia. Both entities were demarcated by the White Carpathians and Small Carpathians (Fig. 1). At the time of its greatest expansion in the last quarter of the 9th century, Great Moravia extended from its original territory in Moravia (Czech Republic), western Slovakia and apparently even Lower Austria into Bohemia, Lusatia, Malopolska, partly the Tisa River region and Pannonia.[3]

The fate of Great Moravia was closely linked with the house of Mojmír and their ambitions and permanent endeavour to assert their own independence from the Frankish empire. The first historically documented prince of Old Moravia Mojmír I. (?-846) expelled Pribina around the year 833 from Nitra and thus apparently laid the foundations of a new state.[4] The power growth in the reign of Rostislav (848-870) drew Great Moravia more and more frequently into conflict with the Eastern Frankish Empire. In order to rid himself of the dependency on Frankish bishops and to gain international recognition as an independent ruler, Rostislav strove to establish an independent Moravian church diocese. This was only accomplished by his successor, Svatopluk (871-894) in the year 880. Establishment of the Methodius Moravian-Pannonian archbishopric under the direct jurisdiction of Rome strengthened the position of Svatopluk as the supreme ruler and provided him with the patronage necessary to evangelise within his domain of power. The following phase may be designated as the true era of the "Great Moravian Empire", the period of greatest territorial expansion of the state. The death of Svatopluk 894 marked the beginning of the break up of the Great Moravian Empire. The individual annexed territories gradually gained independence. Despite the effort to renew the state by Mojmír II (894-906), Moravia, weakened by its internal disputes as well as its wars with the Franks, succumbed in the years 905-906 to the pressure of the Magyars. The state structure disintegrated, the power of the nobles, if it survived the downfall of the state, was restricted to their domains. Apparently, the church organisation survived the state's downfall, but there exist certain records documenting the resurgence of the pagan cult.[5]

1.3 The socio-economic and political structure of Great Moravia

Both written records and archaeological sources imply the significant proprietary and social differentiation of Moravian society.[6] On the one hand, we find the privileged echelons of society – the ruler, dukes (*kъnędzi, principes)*, nobles (*velъmoži, primates, opimates a nobiles viri*) and free tenants, and on the other we find inhabitants in various degrees of dependency. In the case of the privileged, these were a dynastic and proprietary aristocracy of private owners. Private ownership, according to the *Zakonъ sudnyj ljudem* Code of Law incorporated villages, estates, houses, fields, vineyards, money, serfs, horses, herds of livestock, various objects etc.

The lowest echelon of the social hierarchy was represented by slaves, i.e. paupers and people with no rights, sold or made over either along with the farms on which they worked or independently. These were not the only individuals without any rights, and they did not play a deciding role in the

1999; for the archaeological excavations and sources generally Poulík 1985.

3 For the geographic extent of Great Moravia see Havlík 1964, Fig. after page 208 and 256; Dekan 1980, Fig. on the page 84-85; Měřínský 2006. We leave aside the "heretic" theories that place great Moravia in the region south of the Danube, eventually to the Tisa River region and that are objectively rejected by national historians and archaeologists (summary see Mühle 1997; Měřínský 2006).

4 For a somewhat different model see Třeštík 2001, 131–135.

5 For the political history of Great Moravia see Novotný 1912; Havlík 1964, 1978; Wolfram 1987; Profantová 1999; Třeštík 2001; Měřínský 2006.

6 For the social and political structure of Great Moravia see Havlík 1978.

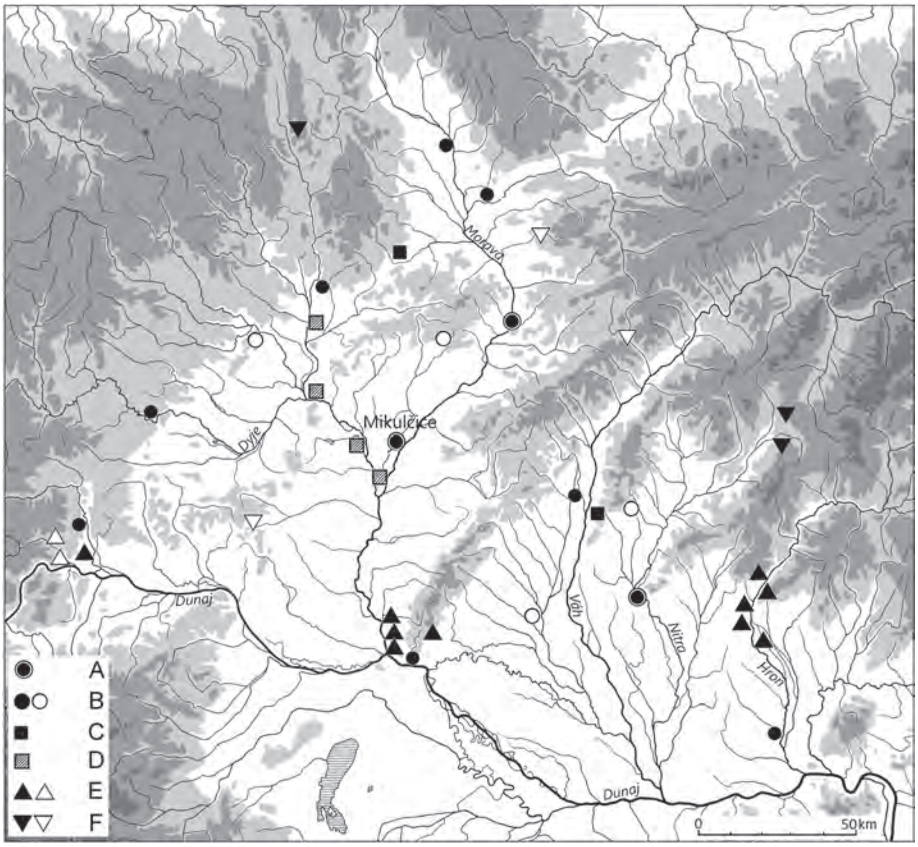

Fig. 1. The centres from the 9th century in Moravia (Czech Republic), south-western Slovakia and Lower Austria according to the formal division of Staňa 1985. A – central strongholds (settlement agglomerations), B – strongholds at the edges of residential and settled regions (provincial strongholds), C – forts on small, steep promontories (strongholds), D – extensive strongholds lacking any distinct division (economic centres with noblemen farmsteads), E – smaller forts in naturally well-protected positions on promontories (frontier defensive line), F – raised forts dominating the countryside, sporadically inhabited (guard forts).

state economy. The largest group in this society included simple people *(prostii ljudьe)*, members of village commons who gradually became legally dependent on the ruler, but otherwise remained politically and economically free. Their taxes, as a ransom for peace and protection, were gradually transformed into a statutory allowance. The slaves and "simple people" began evolving into a group of retainers.

The ruler, a member of the ruling Mojmír dynasty and owner of the land and its inhabitants, stood at the head of the state. According to written records and sources, he was attended by dukes with whom he held council. The dukes (*principes*) were apparently distinguished from the other category, designated as "the Moravians". It is a question to what extent these so-called Moravians overlap with the Moravian nobles (*primates, optimates, nobiles viri*). The central political power was concentrated at the ruler's court and relied on a system of strongholds that apparently corresponded to the eleven "*civitates*" of the Moravians, mentioned in the Bavarian treatise "*Descriptio civitatum at regionum ad septentrionalem plagam Danubii*".

A visible sign of the proprietary relationship of the state (ruler) was the exploitation of village commons by introducing tax and labour obligations and their subordination to the administrative and judicial organs of the state and ruler. Apart from the administrative, judicial and fiscal organisation, a paramount role was played by the executive power of the ruler and his apparatus. This was basically a military organisation that ensured the safety and security of the state within and especially outwards. This function was mainly ensured by the ruler's military company, which formed the core of the military forces of Moravia. Its members included nobles, as well as other privileged classes. At first, their reward was material, from the captured booty and then from tributes. Eventually, parts of the tributes and proceeds were conferred on them and later still, they were rewarded with the contingent demesne of land and people.

The army consisted of both cavalry and infantry, mostly represented by free, humble people who often served with their own horses in the cavalry. We have been graphically informed about the military capabilities of the Moravians by the numerous reports regarding their military campaigns and battles, especially against the East Frankish Empire. The soldiers were armed with spears, long-bows, pikes, axes and swords (Ruttkay 1982, 2002b).

Church organisations were also a component of the state apparatus. The inclination of Moravian rulers towards Christianity as an official ideology of the Moravian state in the 9th century played a fundamental role. The Pannonian archbishopric acquired a seat in Moravia in 873 and was designated as Moravian in 880, although canonically, it was still a Pannonian archbishopric (Třeštík 2001; Marsina 2001; Měřínský 2006).

1.4 Adoption of Christianity and learning

Christianity extended into Moravia no later than the beginning of the 9th century, in connection with the missionary activities of the East Frankish episcopacy and the Aquiline patriarchate in Pannonia. The initial stages of the Christianisation of Great Moravia were apparently unrestrained and mainly involved the prince and his military company. Around 830, Pribina's church in Nitra was consecrated by Adalram, the archbishop of Salzburg, although Pribina remained a pagan for some time yet. In 831, Reginhar, the bishop of Passau, "baptised all Moravians" i.e. Mojmír and his faithful. Iconoclastically, Moravia fell under the power of the bishop of Passau who administered it through his archipresbyter. The country was thus exposed to a strong cultural, but at the same time political, influence of the Frankish Empire (Vavřínek 1963a, 1963b; Měřínský 2006).

In 863, at the request of the Prince, the Byzantine Emperor sent to Moravia a mission led by the brothers Cyril (Constantine) and Methodius. They founded their missionary activities on translations of Biblical texts into the Slavic language. For this purpose, Constantine created a special alphabet – the glagolic alphabet. In contrast to the practices of the Frankish missions, which used the Slavic language only to a necessary extent in the interpretation of the basic articles of the Christian faith, the Moravians had for the first time the opportunity to hear the texts of the Holy Writ in a comprehensible language. Twice – in 868 and 879 – Methodius successfully vindicated his missionary activity based on the Slavic liturgy in front of the Pope in Rome. On this occasion, Methodius and his disciples were ordained and Methodius was confirmed as the archbishop of Pannonia and Moravia. Constantine entered a monastic order in Rome and died there in 869. The schism between the Eastern and Western Christian Church, though, deepened in Moravia under the rule of Svatopluk. After the death of Methodius in 885, Slavic clerics were expelled from Moravia and they sought refuge in Bulgaria, which became the heir to the work of the Cyril and Methodius mission in Moravia. The development of the Moravian archdiocese culminated in the year 900, with the arrival of Latin clergy – one archbishop and three other bishops who were sent by the pope at the request of Mojmír II (Vavřínek 1963a; Vavřínek 1963b; Dvorník 1970).

Thanks to the mission of Cyril and Methodius, learning in Moravia reached an exceptional level. Constantine's and Methodius' idea to create a literature in Slavic language had no parallel in Middle Age Europe at the time. A complete translation of the Bible, Psalter and all necessary liturgy texts was made. On the basis of Byzantine model, Methodius compiled a secular and clerical code of law (*Zákon sudnyj ljudem* and *Nomokanon*), which did not win official acceptance. A remarkable work of the disciples of Constantine and Methodius were the magnificent legends – the Old Church Slavonic lives of both brothers (Vavřínek 1963a; Vašica 1966; Vavřínek 1986).

1.5 Archaeological sources

Archaeology plays a leading and unique role in understanding the history of Great Moravia. The phase of large-scale archaeological excavations in the 1950s to 1980s uncovered a great amount of source material (Fig. 2; Poulík 1985), whose critical processing and analysis is a task that will

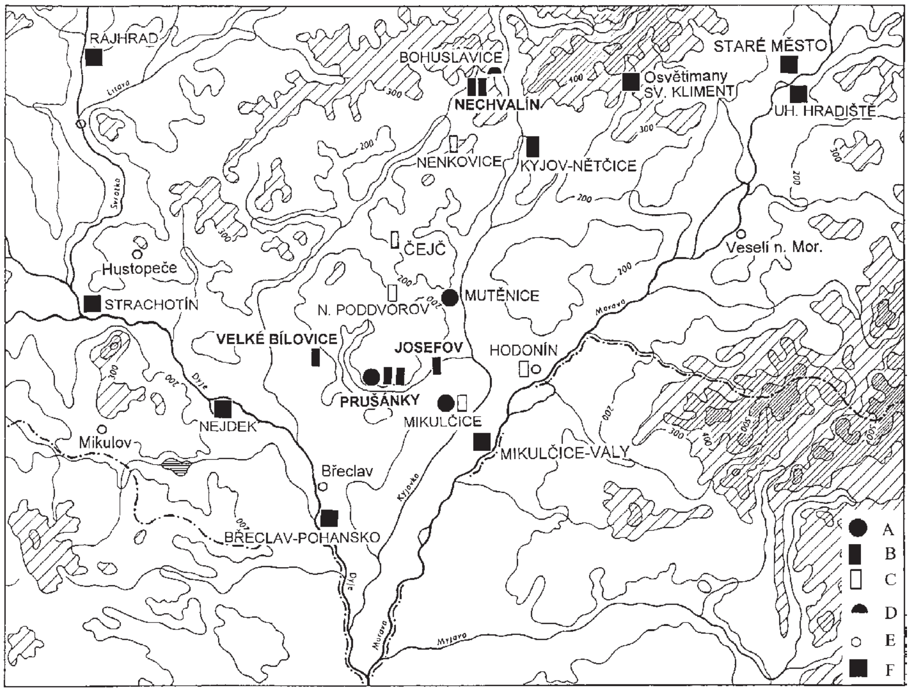

Fig. 2. A map of the most prominent Early Middle Age settlements and burial sites in the wider surroundings of Mikulčice, the research of which involved employees of the Mikulčice base of the Institute of Archaeology of the Czech Academy of Science in Brno in the years 1954-2007. A – settlements, B – "completely" explored burial sites, C – partially explored burial sites, D – partially explored burial-mound necropolises. The two remaining letters represent the cities and towns of today (E) and the Great Moravian strongholds (F) as landmarks. Amended according to Staňa 1996b.

take decades to complete (e.g. Staňa/Poláček 1996). Historically, this phase of the Great Moravian state falls into the period between the decline of the Avar kaganate at the end of the 8^{th} century and the arrival of the Magyars at the beginning of the 10^{th} century. According to the archaeological periodisation, the Great Moravian relics are classified as belonging to the Middle 'Hilfort' period (800-950). At the same time, the first half of the 10^{th} century is viewed as the period of the decline of Great Moravian structures.

The fundamental supporting blocks of the state were the strongholds in their role as centres of political power, of clerical and economic authority, of crafts, trade and learning. The strongholds rank among the best explored objects of the 9^{th} century in Moravia (Fig. 2). Of at least 30 fortified settlements on the territory of Great Moravia, central strongholds (*zentrale Burgwallstädte*) are most important, as the seats of the holders of the main political power in the state (Mikulčice, Staré Město-Uherské Hradiště, Nitra). These are extensive and rugged residential complexes with fortified and non-fortified formations, extending tens of hectares in size, with more church buildings, rich burial sites and many valuable findings. Of these centres, only Nitra can be associated with references in written sources (Nitrava), although the principal centre of Great Moravia must have been located on the territory of Mikulčice or Staré Město-Uherské Hradiště (both localities lie in the flood plain of the middle stream of the Morava River). Attempts to identify one of these with the "*inefabilis Rastici Munitio*" and "*urbs antiqua Rastici*" of the Fulda annals (869, 871), or with the capital centre of the state have been unsuccessful. Similarly, the issue of the location of Methodius' seat with the cathedral and the site of the archbishop's grave remains open, despite the most probably localisation being at Sady near Uherské Hradiště. The cited central strongholds could also have included Olomouc; Zalavár, the principal stronghold of the Platten principality, also meets these criteria (Štěpánek 1965; Staňa 1985; Měřínský 2001).[7]

Churches are among the most significant discoveries in the strongholds (Fig. 3). They were discovered at seven localities in the central region of Great Moravia. These include the settlement agglomerations in the area of Staré Město-Uherské

7 For specifical funktion of the stronghold et Břeclav-Pohansko see Macháček 2007.

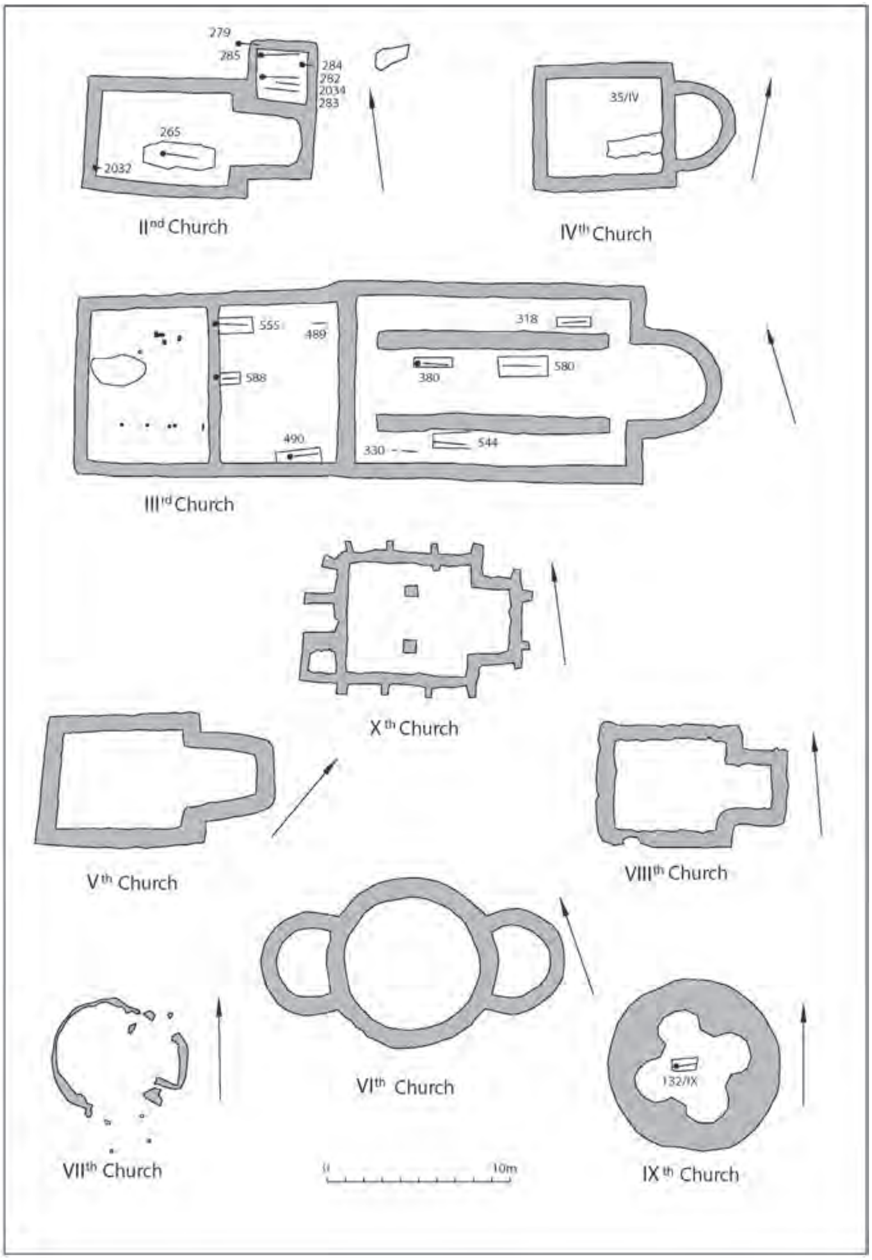

Fig. 3. Ground plans of the churches in Mikulčice with interior graves and graves disturbed by foundations denoted.

Hradiště and Mikulčice, as well as the stronghold of Břeclav-Pohansko and possibly Bratislava, Devín, Ducové and Nitra. Church or generally walled structures have been indirectly documented at other localities.[8] The Mikulčice three-nave basilica (the 3rd. church), and the cathedral complex in Sady near Uherské Hradiště hold an exceptional position. Both architectures stand out among the other Great Moravian churches thanks to their size, disposition, complicated building development, the presence of graves (apparently dynastic) in the main church premises and the concentration of richly equipped noble graves with swords, gold jewellery, ostentatious garnitures of wrought girdles and spurs, coffins wrought with iron bands etc. located in the neighbouring burial sites (Fig. 4).[9]

8 For the archaeological problematic of the Great Moravian churches see POŠMOURNÝ 1971; POULÍK 1978; VAVŘÍNEK 1980; KLANICA 1985c; ŠTEFANOVIČOVÁ 2001; RUTTKAY 2002a; GALUŠKA/POLÁČEK 2006; MĚŘÍNSKÝ 2006; POLÁČEK 2008a.

9 For the archaeological research of the Mikulčice basilica see POULÍK 1975; KLANICA 1985c; SCHULZE-DÖRRLAMM 1995; GALUŠKA/POLÁČEK 2006; POLÁČEK 2008a; for the supposed grave of arcbishop Methodius in Mikulčice basilica see problematically KLANICA 1993,

Fig. 4. One of the magnate's graves with sword at the III[th] church in Mikulčice. Photo Archive AI ASCR Brno.

The churches were mainly surrounded by burial sites. The largest of these included the necropolises near the church "Na Valách" in Staré Město, near the III[rd.] church, basilica, in Mikulčice and near the church in Břeclav-Pohansko (Hrubý 1955; Poulík 1975; Kalousek 1971). From the aspect of the representation of graves with gold jewellery, the richest group was that from the church complex in Uherské Hradiště-Sady (Galuška 1996; Staňa 2001). The differences in the equipment ("richness") of the necropolises need not only reflect different social and proprietary conditions of the respective communities, but also, for example, different degrees of Christianisation. It is probable that the proportion of traditional (pre-Christian) customs, including the burial of gifts with the dead, receded during the 9[th] century, especially under the influence of Church prohibition. This most probably explains the absence of arms, vessels and other grave additions in otherwise richly equipped burial sites of the late 9[th] century. In contrast to churches whose function practically ended with the downfall of the Great Moravian state and its principal centres at the beginning of the 10[th] century, interments continued to some extent at some church burial sites for some time during the 10[th] century (Dostál 1966; Klanica 1985c; Měřínský 1986).

Apart from church cemeteries, there existed in strongholds and their immediate vicinity simple burial sites that in some cases demonstrated signs similar to those of the "richest" burial sites near churches (e.g. "Kostelisko" in the suburb of Mikulčice fortified centre; Klanica 1987b).

Archaeological research of churches and simple necropolises uncovered extensive and valuable findings. This is a basic source of knowledge and understanding of the social structures and material culture of the inhabitants of Great Moravia (Dostál 1966; Poulík 1985; Hanuliak 2004). The skeletal material from the graves is an inexhaustible source of information regarding the anthropology, demography and pathology of the Old Slavs (Stloukal/Vyhnánek 1976). In the case of grave findings, these often include masterful artistic handicraft products, which to a certain extent characterise the court culture of Great Moravia. An example of this may be the luxurious jewellery, garnitures of wrought spurs and girdles and other decorative objects. In the first half of the 9[th] century, handicrafts in Moravia were affected by the declining influence of the Avar molten metal industry and especially by contacts with the Carolingian milieu.[10] At the

1994; critical e.g. Staňa 1996a; generally Měřínský 2006. For Uherské Hradiště-Sady see Galuška 1996.

10 A diverse group of bronze cast, gold-plated fittings and spurs, often decorated using the notching technique, and iron fittings and spurs, sometimes with Tauzin decoration is generally termed, rather problematically,

Fig. 5. Position of Mikulčice in the frame of Czech Republic.

beginning of the second half of the 9th century, new influences intensified, infiltrating into the Old Moravian milieu from Byzantium and the Orient. The jewellery of "Byzantine-Oriental" ("veligradian") character with assorted variations of gold, sliver or gold-plated bronze earrings and rings whose decoration mainly applied filigree and granulations became an important component of the production of home workshops in the second half of the 9th century. Hollow buttons (gombíky), which were a characteristic part of the clothes of old Moravians, represented a distinctive and varied group of local handicraft products. The specific types of Old Moravian jewellery demonstrate the existence of several centres of jewellery production, associated with important centres of power (Staré Město, Mikulčice, Nitra, Pohansko u Břeclavi) and other local centres (Dolní Věstonice, Rajhrad). It is probable that the production of veligradian jewellery ended with the downfall of the Great Moravian state formation at the beginning of the 10th century, when the producers probably left for the perspective, especially Czech, centres (Stará Kouřim, Prague). A numerous group of handicraft products carried Christian symbols (crosses, captorgs, ironwork in the shape of the cross, styled depictions of Christ, the saints, fish, birds, etc.).[11]

2. The power centre at Mikulčice

2.1 Significance

The stronghold of "Valy" near Mikulčice, along with the agglomeration in the area of Staré Město-Uherské Hradiště, ranked among the most important centres of Great Moravia. Unfortunately, neither of these centres can be unequivocally identified with the locations cited in contemporary written sources. The importance of this locality from the aspect of today's research lies in its relative preservation, in that it is undamaged by later city developments as in the case e.g. of Staré Město-Uherské Hradiště. The other merits of this locality are the relatively developed stratigraphy, the rich findings, including a number of luxurious and archaeologically valuable objects, as well as the partial preservation of wood. This all makes the Mikulčice stronghold locality unique, enabling the study and resolution of archaeological and historical issues inaccessible elsewhere (Poláček 1996 with lit., 2001b; Poláček/Mazuch/Baxa 2006).

2.2 Natural conditions and the topography of the settlement

Mikulčice lie in the south-eastern tip of the Czech Republic (Moravia), on the border with Slovakia, about 7 km south-westerly from Hodonín (Fig. 5).[12] The "Valy" stronghold near Mikulčice is located in the geo-morphological complex of the Lower Morava River valley, approximately in the middle of the flood plain of the Morava River, between the Czech (Moravian) Mikulčice and the Slovak Kopčany. The width of the flood plain here is around 6 km (Fig. 6, 7).

The landscape of the flood plain, where the stronghold was located, had quite a different character in the 9th century that it does today. It was a terrain broken up by sand dunes, the rest

the Blatnica-Mikulčice style/horizon (Poulík 1963; Bialeková 1980, 1996; Wachowski 1992; Profantová 1997; Měřínský 2006).

11 For the problematic of artistic handicraft production of the Great Moravia see Eisner 1947; Hrubý 1955; Poulík 1963; Dostál 1965, 1991; Benda 1963, 1965; Capelle 1968; Klanica 1970, 1974; Dekan 1980; Galuška 1989; Staňa 1995; Pavlovičová 1996; Štefanovičová 2004; Profantová/Frána 2003; Ungerman 2002, 2005.

12 The exact positron of the stringhold: 48˚48‘16“ north latitude and 17˚05‘29“ east longitude.

Fig. 6. Aerial image of the meadow enclave with the „Valy" stronghold near Mikulčice from the west. In the background, the buildings of the Kopčany village with the second sector of hinterland settlement, as well as the slopes of the Chvojnice hills. Photo M. Bálek.

Fig. 7. Aerial image of the meadow enclave with the „Valy" stronghold near Mikulčice from the east. In the background, the buildings of Mikulčice village with the second sector of hinterland settlement; also, the slopes of the Kyjov hills. Photo M. Bálek.

consisting of shingle terraces and a thick network of river channels. The landscape was not flooded, as it has been in the last centuries. In the 8^{th}-9^{th} century, it apparently provided the best conditions for life. The vegetation was characterised by tough woodland with a predominance of oak, elm and ash. The woods were open and backlit due to forest clearing, pasture and collection of twigs. The land closely surrounding the Great Moravian stronghold was of a partially park-like character with variously large areas of pastures, meadows and possibly fields (Opravil 1972, 1998, 2000, 2003).

The presence of sand dunes in this part of the flood plain was important from the aspect of conditions for settling and populating. These dunes date from the advent of the Pleistocene and Holocene and represent the most significant location of prehistoric and Early Middle Age settlement. These positions were sought out especially for their dry, heating surface and their slight elevation above the lowest parts of the countryside afflicted by humidity and ground inversions. The elevations of the sand dunes around the stronghold were also a favourite place for founding burial grounds (Poláček 1997; Havlíček/Poláček/Vachek 2003; Culek/Ivan/Kirchner 1999).

Intense expansion of settlements into the less favourable lower localities consisting of flood-loams, took place especially in the later Great Moravian period, in the second half of the 9th century. The reason for this was not only the demographic growth of the agglomeration's population, but also the displacement of the original inhabitants of the *acropolis* by the foundation of churches and their sacral grounds (Poláček 1997; Staňa 1997; Poláček/Mazuch/Baxa 2006).

Beginning in the 10th century, post-Great Moravian settlements again retreated to the elevated positions of the sand dunes. The reason for this may have been the incipient floods that began occurring repeatedly in cycles from around the 13th century. These changes led to the degradation of the original cultural landscape of the flood plain into an uninhabited land, henceforth exploited only as a subsidiary farming space. The originally broken up landscape with islands and branching river beds disappeared below the detritus of young flood-loams (Poláček 1996, 1998a, 1999, 2004).

The agglomeration of the settlement complex in Mikulčice originally occupied several islands among the network of the Morava River channels. The pre-Great Moravian, apparently fortified, central 8th century settlement occupied an elevated formation of half-moon shape at the site of the later bailey and northern part of the *acropolis*. Expansion of this formation to include the area of "Dolní Valy" located below this and the building of new fortifications gave rise in the 9th century to the Great Moravian stronghold itself. This consisted of the *acropolis* covering an area of 7.7 hectares and the bailey covering an area of 2.4 hectares. The suburb gradually grew around his fortified core (Poláček/Marek 1995; Poláček 1996; Poláček/Mazuch/Baxa 2006).[13]

The most significant walled structures existed in the 9th century in the northern elevated section of the *acropolis* – at least four churches and a palace (Fig. 9). These were surrounded by an extensive burial site. This was the main residential area of the agglomeration – the Prince's residence. On the other hand, no churches or burial sites were found in the area of the fortified bailey. This was purely a residential area with dense, regular development, apparently an estate housing the military retinue of the prince (Poulík 1975; Poláček/Mazuch/Baxa 2006).

The *acropolis* and bailey as the fortified core of the agglomeration were surrounded by the suburb (Fig. 10). This term refers to the settled area over a range of 700 m around the fictional centre of the agglomeration. This demarcation is merely a working convention that requires further verification. The settled area of the suburb, originally estimated to cover 100-200 hectares, actually covered maximally 30 hectares. In the suburb, there existed several churches, settlements and burial sites. The settlements had a partial artisan character and livestock breeding also played some role. The local inhabitants evidently participated in ensuring the running of the centre and in providing services for the privileged classes. It is thought that the churches in the suburb were parts of the estate founded by the nobles in the vicinity of the Prince's residence (Poláček/Marek 2005; Poláček/Mazuch/Baxa 2006; Hladík/Mazuch/Poláček 2008).

The most distinctive settlements and burial areas of the suburb were located on the sand dunes in the immediate vicinity of the fortified centre. This area included the "Těšický les" in the north-east and "Kostelisko" in the south (Fig. 11). Extensive burial sites existed in both

13 In the following anthropological part of this book are used different terms: *acropolis* and bailey as a fortified centre of the agglomeration = castle; suburb at area beneath the walls = sub-castle.

Fig. 8. Mikulčice-Valy, Great Moravian stronghold with suburb. Diagram of the topographic situation. Caption: 1 – *acropolis* ramparts, 2 – archaeologically documented fortification of the baily, 3 – outer ramparts on the eastern perimeter of the "Těšický les" in the suburb, 4 – terrain crests of the elevated sections of the *acropolis* and suburb, 5 – established numbering of churches and palace, 6 – expected course of the original river channels.

these positions in the 9th century. Approximately in the second half of the 9th century, we become the witnesses of a significant increase in the settlement of the sections of the suburb located further below, on the flood-loams. This mainly involved the area of the north suburb (Poláček/Marek 2005; Hladík/Mazuch/Poláček 2008).

The natural protection of the centre was ensured by the river channels, which on the one hand spanned the fortified core of the agglomeration and on the other divided the area of the suburb. For the life of the stronghold, these channels were not only of strategic but also of economic importance. These channels could be surmounted by three wooden bridges (Poláček 1997, 2007 with lit.).

As early as the 8th century, Mikulčice were an important centre of power. The presence of the social elite here is documented especially by the large collection of spurs with hooks and Avar bronzes.[14] In the 9th century, Mikulčice became the centre of political power of the ruling Mojmír dynasty. The importance of the military function of the stronghold is illustrated by the findings of arms and riding tackle. The court culture is represented by the remarkable products of local handicraft as well as luxurious objects of foreign provenance (Fig. 12; e.g. Poulík 1975, 1986). The superior standard of living of the ruling class also included a diverse diet supplemented by fruits, vegetables, apices, wine etc. (Opravil 2000). Mikulčice were an important centre of Christianity as illustrated by the concentration of churches, the findings with Christian symbols, as well as documents affirming the level of learning at the time (Poulík 1970;

14 Klanica 1986, 1995; Poulík 1988; Zábojník 2005; Poláček 2008c.

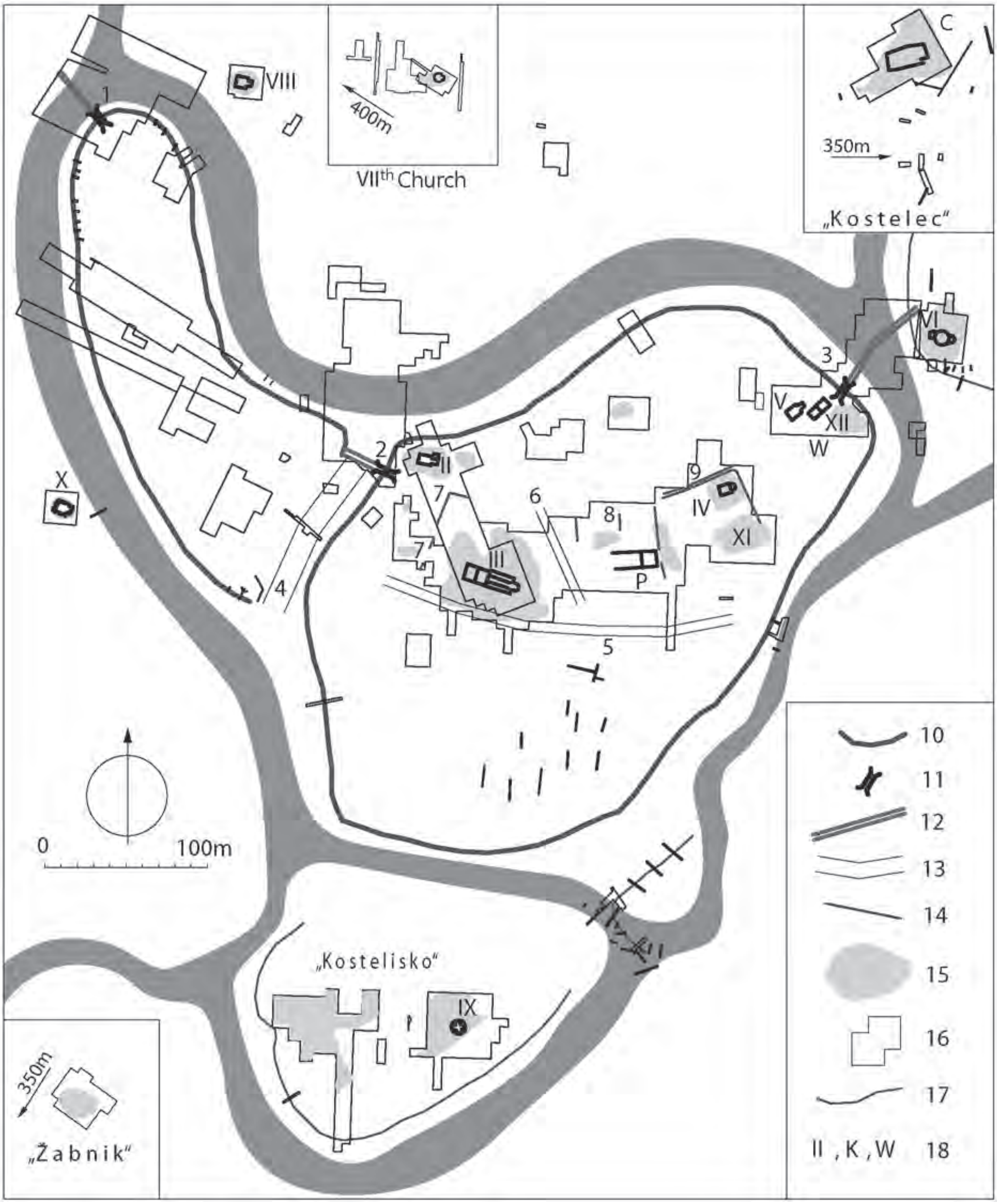

Fig. 9. Mikulčice-Valy, the stronghold of the 9th century. Ground plan of the stronghold with identification of the most significant objects: 1 – north-west gate of the bailey, 2 – western gate of the *acropolis*, 3 – north-east gate of the *acropolis*, 4 – ditch between the *acropolis* and bailey, 5 – ditch south of the IIIrd church, 6 – ditch between the basilica and palace, 7 – palisade wall of the area around the basilica, 8 – traces of palisade walls north of the palace, 9 – road and fence of the area around the IVth church. Legend: 10 – fortification, 11 – gates, 12 – bridges, 13 – ditches splitting the internal area of the fortified centre, 14 – fences and palisades inside the *acropolis*, 15 – burial places or significant groups of graves, 16 – investigated area, 17 – significant terrain edges, 18 – established numbering of churches, identification of the palace on the *acropolis* (P), pagan temple in the place called "Klášteřisko" (C) and jewellery workshop by the Vth church (W).

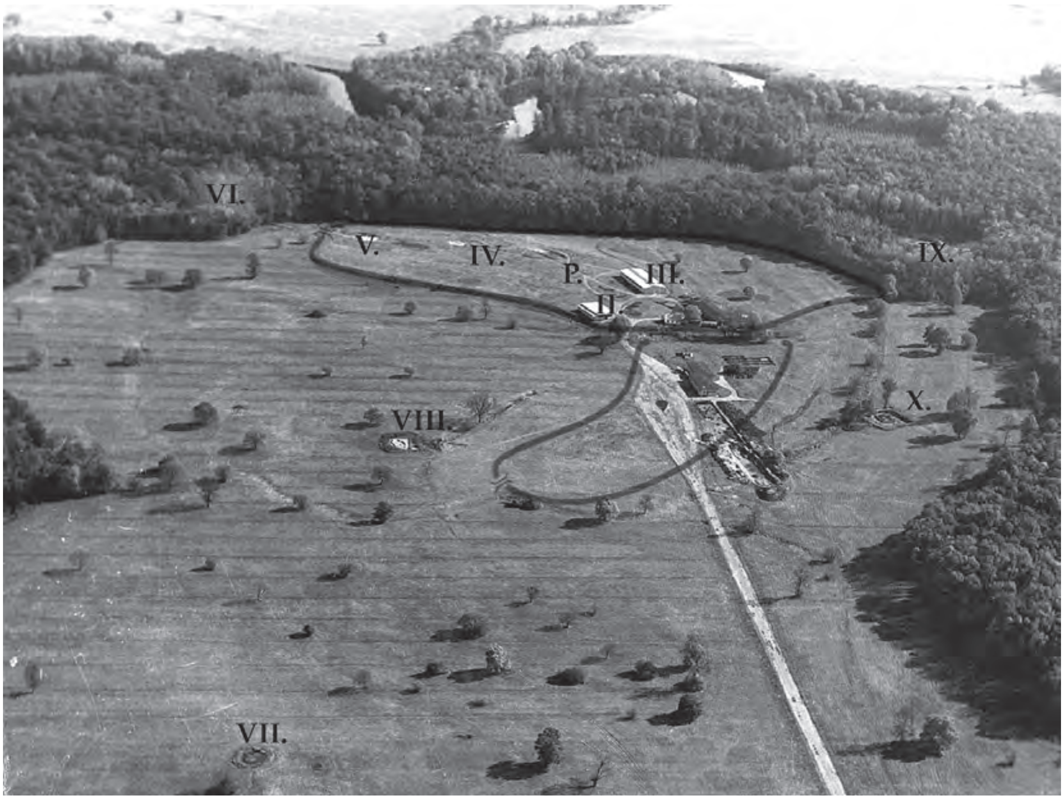

Fig. 10. Mikulčice-Valy. Aerial image of the stronghold from 1964 with the course of the fortifications and the positions of walled structures – churches and palace – denoted. View from the north-west. In the background, the meanders of the Morava River, regulated at the beginning of the 1970s. Photo Archive of AI ASCR Brno.

Klanica 1993). On the other hand, the supposed existence of a pagan temple dating to the second half of the 9th century at the summit of one of the dunes in the suburb ("Klášteřisko"; Klanica 1985b) is difficult to explain.

As the foremost centre of Great Moravia, Mikulčice shared the fate of the whole state. At the beginning of the 10th century, they fell to the Magyars who apparently significantly damaged the stronghold and surrounding settlements. Life continued to a restricted degree, though. This is attested by documents of reduced settlement in the 10th to 13th century. It is possible that a certain centre of local power remained, although some historians refute this (Měřínský 1986; Třeštík 1991; Poláček 1998a, 1999).

2.3 The state of archaeological research

"Valy" near Mikulčice were discovered for science and the public by Josef Poulík in 1954 (Poulík 1957). This discovery was followed by 38 seasons of systematic field research, which uncovered an area of almost 5 hectares (Fig. 13, 14). These excavations are especially associated with the names of J. Poulík and Z. Klanica (Poulík 1975; Klanica 1985a). Mikulčice found their place among the most significant European archaeological localities. The rich source material thus acquired, though, is still waiting to be processed and made public. It represents one of the main foundations for the historical evaluation of Great Moravia and its role in the development of Early Middle Age Central Europe.

At the beginning of the 1990s, systematic uncovering and exposure was temporarily suspended and the attention of the Mikulčice base of the Institute of Archaeology of the Czech Academy of Science in Brno focused on the processing and evaluation of the results of field works up till then („concluded phase of research, 1954-1992"). Although excavations within the "new phase of research" after 1993 were restricted

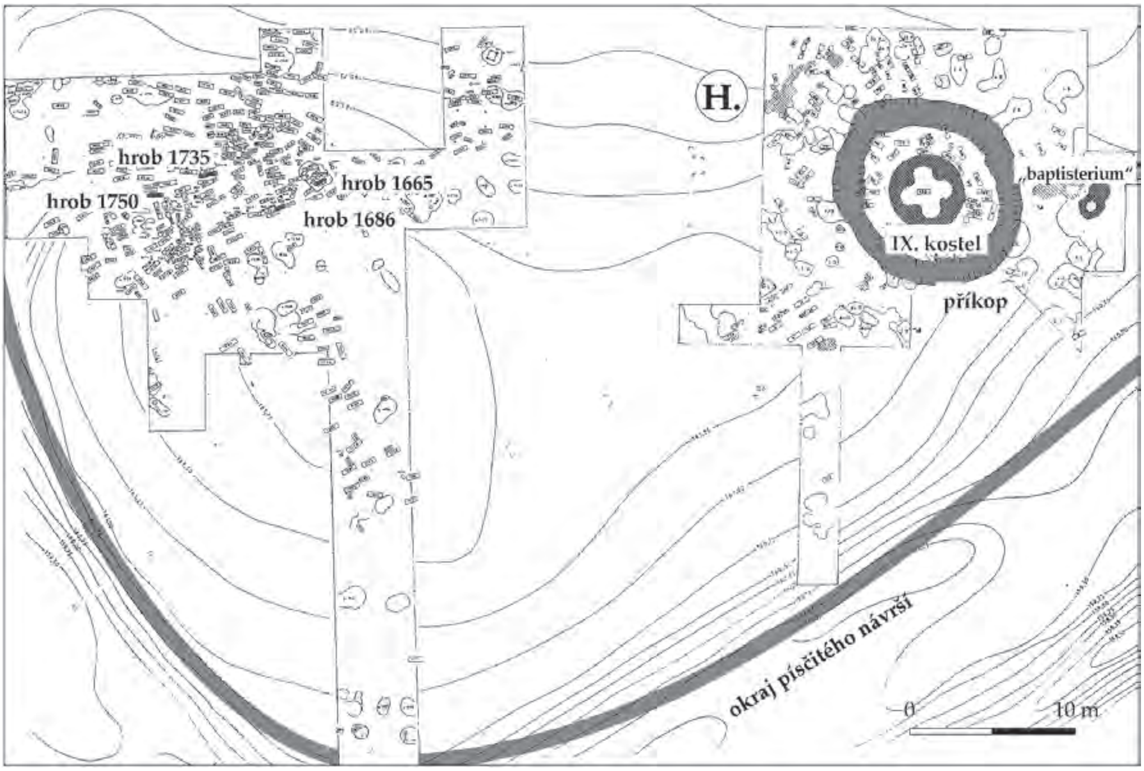

Fig 11. Mikulčice-„Kostelisko". Kostelisko burial site (left) and the cemetery near the IX[th] church in the suburb of the centre. The IX[th] church, so-called baptisterium, the moat surrounding the church from the 14[th]/15[th] century, selected graves and the ridge of the sand dunes are all denoted. According to Poláček 2006.

to a minimum, field works never stopped. It was still necessary to conduct salvage excavations within the area of the stronghold and its hinterland. Apart from this, early on, there arose a need for new field works in association with the verification of the contentious issues of the processing of old research. This is why a long-term program of "source processing and verification of old research" was launched in 2004. Up to now, the work within this program has focused especially on the study of the settling of the least studied and researched sections of the agglomeration, specifically the suburb and the nearest hinterland (Poláček 1996, 2001b, 2005b).

Simultaneously with the "new phase" of research at Mikulčice, field works continue in the Slovak section of the agglomeration, i.e. on the territory of Kopčany east of the Morava River (district of Senica, Slovakia). Since 1994, the Institute for Monument Preservation in Bratislava has been conducting structural-historical and archaeological research of the chapel of St. Margaret of Antioch as well as the archaeological survey of the Early Middle Age settlement on the whole cadastral territory of Kopčany (Baxa 2000; Baxa et al. 2004; Baxa et al. 2005). The discovery of Great Moravian graves in the close vicinity of the church in 2004 confirmed that this structure dates to the 9[th] century. This is thus the remotest sacral building of the Mikulčice agglomeration and at the same time the only Great Moravian church still standing (Fig. 15). The "Pri Kačenárni" sand dune, where in the 1960s M. Kraskovská excavated the settlement and burial site from the 9[th] century, is located near this chapel (Kraskovská 1965, 1969).

3. The hinterland of Mikulčice stronghold

3.1 Demarcation of the hinterland

The economic hinterland is represented by a hypothetical perimeter with a radius of 10 km, surrounding the fictional centre of the agglomeration (Fig. 16). This demarcation ensues from the estimation of the farmed land necessary to cover the consumption of cereals necessary to feed the assumed 1000-2000 inhabitants of the centre. As the flood plain apparently did not offer suitable conditions for the cultivation of cereals, the necessary arable land had to be replaced by the more distant positions outside the flood plain. Despite this, the perimeter of the agricultural hinterland could hardly exceed 10 km. This demarcation is merely a useful tool; a more reliable means of establishing the internal and external borders of the hinterland could ensue from future analysis of the structure of the settlement around the centre (Poláček 2008b).

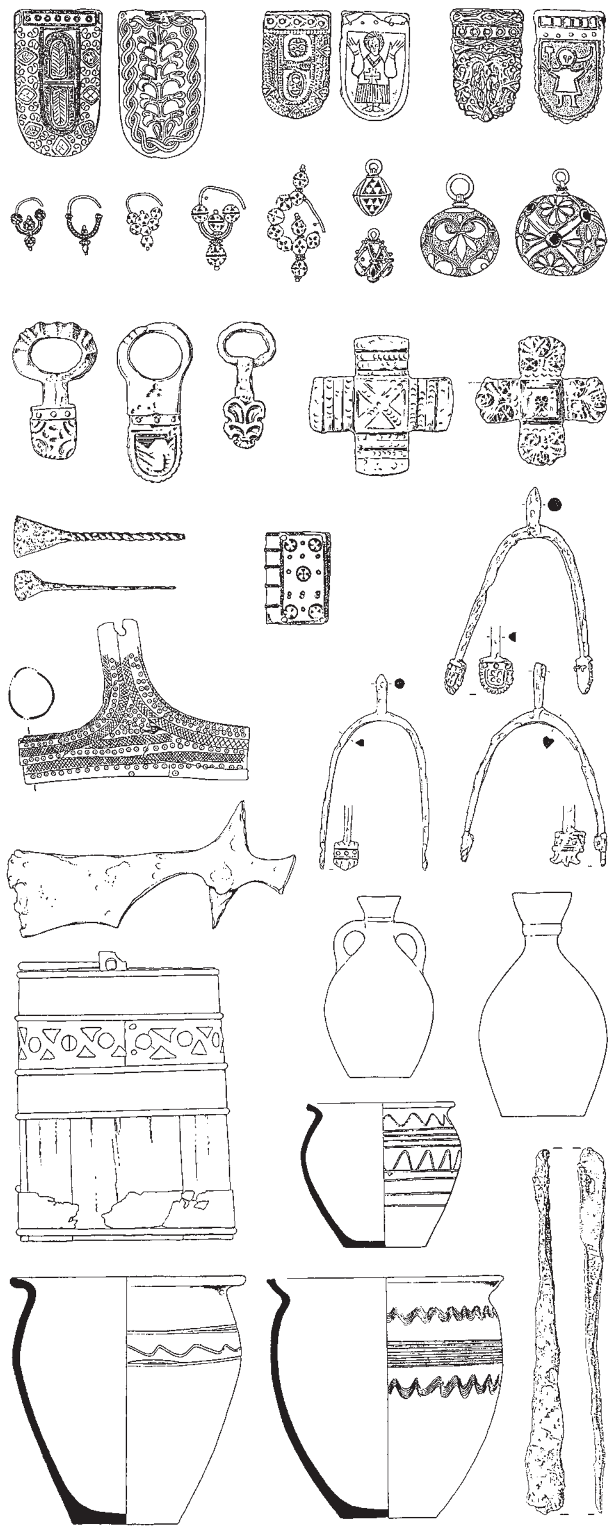

Fig. 12. Mikulčice-Valy. A selection of characteristic findings from the Middle 'Hilfort' (Great Moravian) period. According to Poláček 2006.

3.2 Natural conditions of the hinterland and the course of routes

The studied territory lies in the warmest region of the Czech Republic. The average annual temperature is 9.5° C, the average total rainfall is 585 mm, which in view of the temperature is an above average value and signalises a warm region, relatively well supplied with rain. These are prerequisites for this territory to be very fertile. The relatively increased incidence of rainfall is given by the area's position in front of the windward slope of the Carpathian mountains (Culek/Ivan/Kirchner 1999).

From the aspect of geology and geomorphology, the area of the economic hinterland is divided into three main sectors (Poláček 2008b). The borders of these sectors are orientated in the NW-SE direction, i.e. the same as the Morava River, which forms the axis of the whole studied territory and at the same time the state boundary between the Czech and Slovak Republic. The middle sector represents the flood plain of the Morava River and the Kyjovka flowing in parallel at 156 to 167 m above sea level. The flood plain at the site of Mikulčice is less than 6 km wide.

A flat terrain rises on both sides of the flood plain, and this gradually changes to a hilly landscape with a maximum height of 260 m above sea level. On the north-western Czech-side, these are the Prušánky hills, broken up by shallow valley of the Kyjovka stream and its Prušánka tributary. On the south-eastern Slovak-side, the flat terrain of

Fig. 13. Mikulčice-Valy, acropolis. Excavation of basilica in the year 1957. Photo Archive of AI ASCR Brno.

Fig. 14. Mikulčice-Valy. Excavation of the extinct river-bed in front of north-west gate of bailey. Photo Archive of AI ASCR Brno.

the Borská lowlands gradually rises in the south-eastern direction into the Chvojnice hills.

The course of old routes played a fundamental role in the formation of settlement structures. The main route, passing on a west-east course through the stronghold, has been documented archaeologically in the form of a triad of gates and bridges within the area of the fortified centre. It is at most probable that this communication axis of the stronghold linked up with the long-distance road connecting the district of Brno with Váh River region, as we know it in the form of the so-called Czech road of later historical sources. It is presumed that somewhere in the territory of Mikulčice, this road intersected a communication of a north-south course, following the flow of the Morava River and known as one of the so-called routes of the Amber Road (Květ 1999). In this connection, it is necessary to stress the significance of the river, which in the Early Middle Ages represented an important transportation junction (Poláček 2007).

3.3 The residential network and the structure of the settlement in the hinterland

The 9th century residential network on the Czech side of the hinterland, especially its internal section, is relatively well known thanks to the intense field works as well as surface survey. Three sectors of settlements are involved, each linked to three significant, and from the aspect of natural environment suitability for settlement predestined, lines (Fig. 16, 17). All three lines are similarly oriented to the Morava River. The localities of the first sector at a distance of around 1 km from the centre of the agglomeration are linked to the line of the "Virgásky", "Trapíkov" and "Kněží" sand dunes. The second sector, at a distance of 3.5 km represents the line to the south-eastern slope of the flood plane. The third sector at a distance of 7.5 km corresponds to both sides of the shallow valley dent of the Prušánka stream (Poláček 2008b).

The situation on the Slovak side of the Mikulčice agglomeration is relatively well known in the Kopčany and Holíč cadastre, while the findings in the more distant sections of the hinterland are less reliable. In the flood plain, as on the Czech side, settlement is linked to the sand dunes. These form a belt that runs parallel to the edge of the flood plain, at a distance of approx. 2 km from the stronghold and approx. 700 m from the south-eastern edge of the flood plain (1st sector). All the dunes of this line were settled in the 9th century. Moreover, this line was connected by a transverse belt of elevated and in the 9th century settled terrain with the edge of the flood plain (2nd sector). The second line of settlement on the Slovak side at a distance of 2.5 km from the stronghold is bound to the terrain of the river terraces, bordering the flood plain. It is represented by several settlements and burial sites in the territory of Kopčany and Holíč (Kátov), known especially from surface collections or isolated findings (Baxa et al. 2006; Poláček 2008b).

Fig. 15. The chapel of St. Margita in Kopčany on the Slovak side of the Mikulčice Early Middle Age agglomeration – the only Great Moravian church that remains standing today. Photo Archive of AI ASCR Brno.

Accessibility of the dunes of the first Slovak sector of the hinterland "on dry feet" from the edge of the flood plain was of fundamental importance in the settling of this territory. This is the main difference compared to the Czech side, where the settled positions on the river islands were separated from the elevated edge of the flood plain by a 1.5 km wide belt of non-settled and apparently waterlogged terrain (Poláček 2008b).

The structure of the hinterland settlement reflects to a great extent the geographical possibilities of the nearest surroundings of Mikulčice stronghold. It is probable that within the wider territory of the centre, there existed since prehistoric times an important crossing across the river, later used in the Middle Ages by the "Czech" road and indirectly documented as late as the 17th century. A number of the settlements were situated at the crossing of the river valley, as well

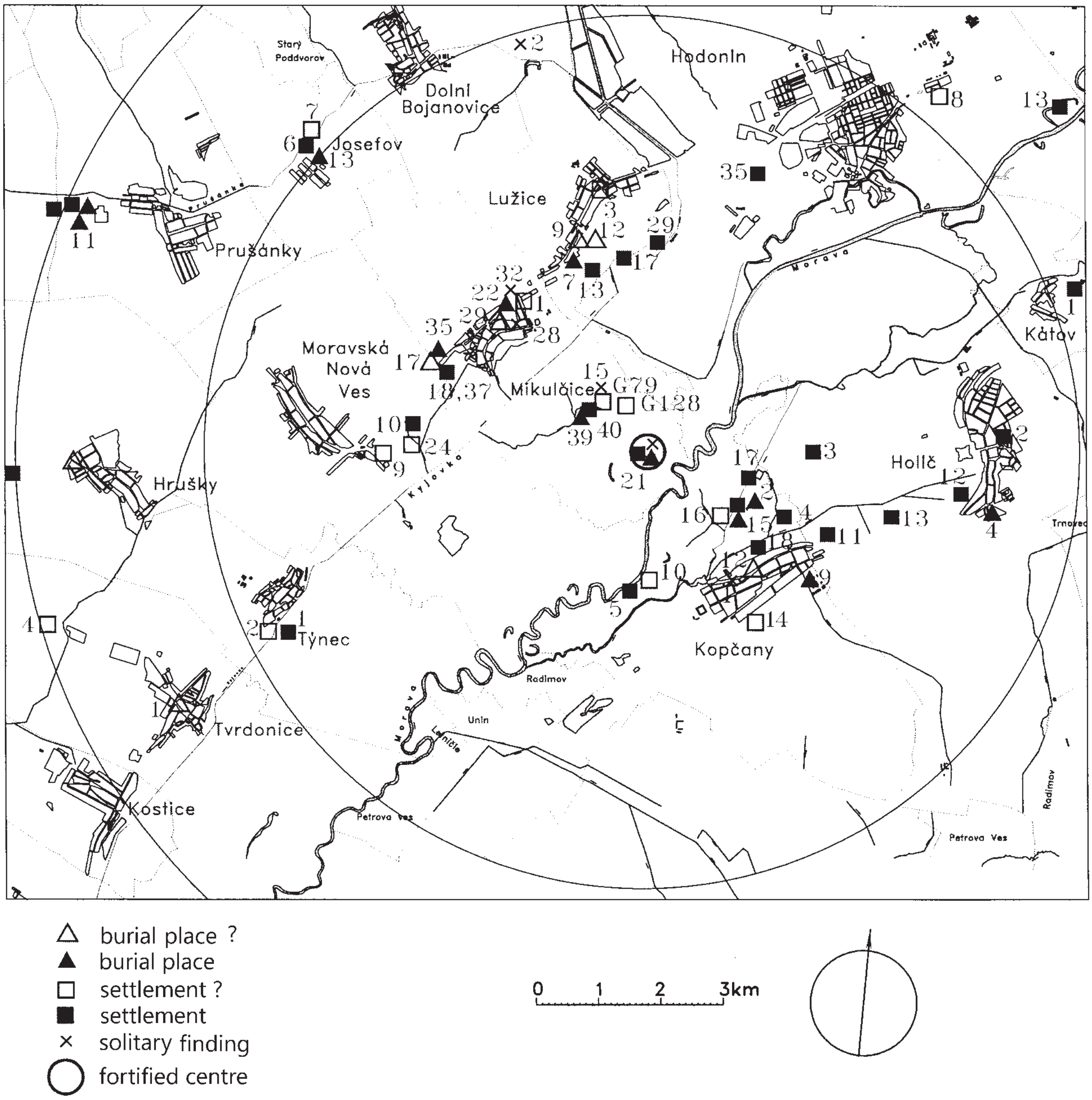

Fig. 16. Middle 'Hilfort" period („Great Moravian") settlement of the hinterland of Mikulčice stronghold with a denoted perimeter of 7 and 10 km around the centre of the agglomeration. The fortified centre of Mikulčice-„Valy" (21). The localities are numbered according to the single cadastres; this corresponds to the archaeological topography in the hinterland of Mikulčice stronghold (Škojec 1997, 1998, 2000, 2005; Klanicová 2000; Baxa et al. 2006) and the mapping of the settlement of the sand dunes in the flood plain of the Morava River (Poláček/Škojec/Havlíček 2003). According to Poláček 2008b.

as along the routes headed inland on the Czech and Slovak side of the border (Poulík 1975; Květ 1999; Poláček 2008b).

3.4 The issue of the socio-economic structure of the hinterland

The state of knowledge regarding the socio-economic structure of the hinterland of Mikulčice centre is today imperfect and one-sided. On the one hand, we lack published or otherwise accessible results of field works, and on the other the current image is mainly based on the burial sites. The weakest aspect of current knowledge is the insufficient research of the settlements.

The view of the social structures of the Mikulčice centre hinterland has undergone much

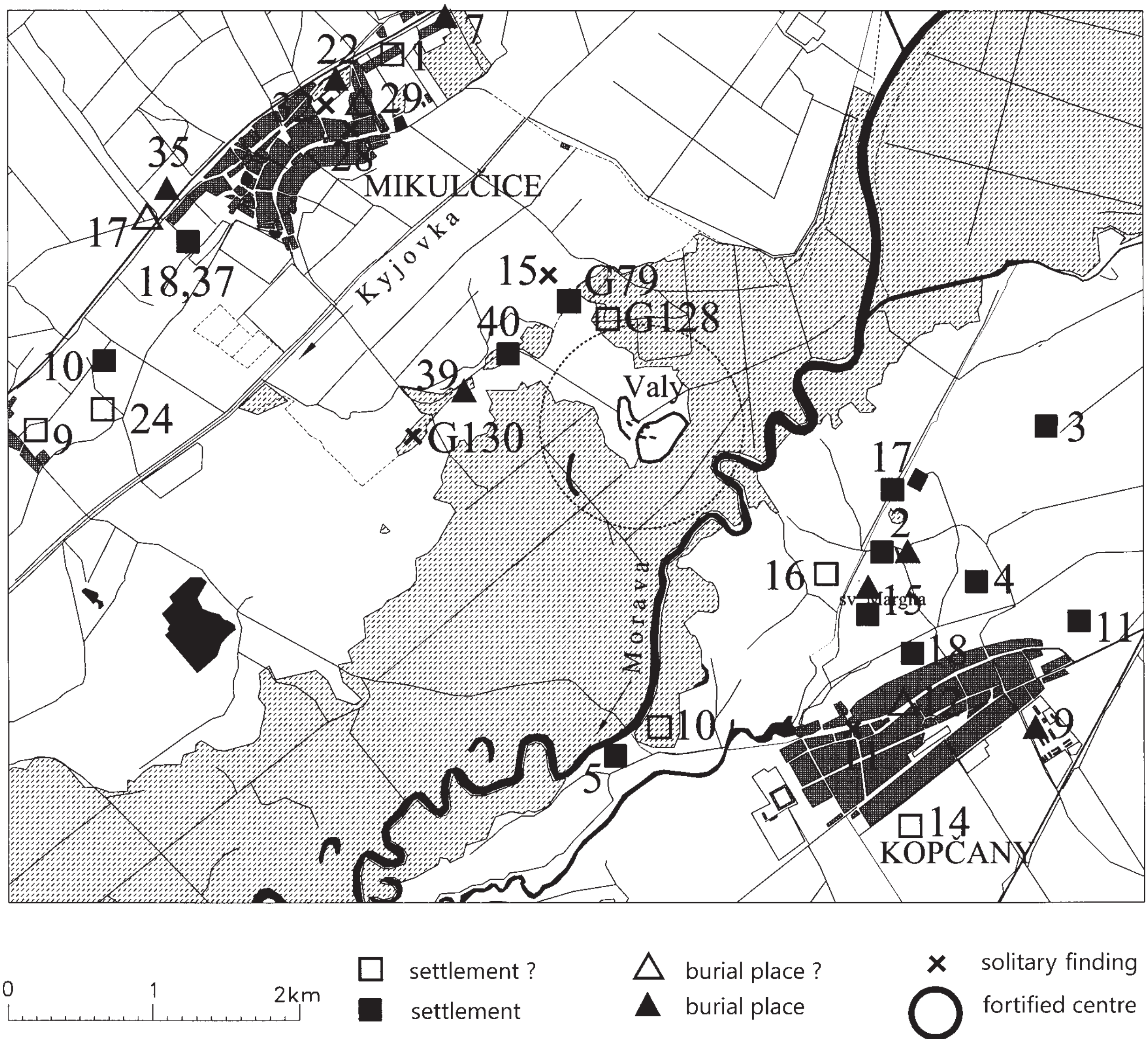

Fig. 17. Middle 'Hilfort' period („Great Moravian") settlement of the closest hinterland of the stronghold. Denoted external border of the suburb (circle with a radius of 700 m). The first sector of hinterland settlement on the Czech side (from the left): G130, 39 – Mikulčice-„Virgásky", 40 – Mikulčice-„Trapíkov", 15 – Mikulčice-„Kúty" („Kněží"?), G79 – Mikulčice-„Kněží", G128 – Mikulčice-„Za Mysliveckou chatou". The second sector of hinterland settlement on the Czech side (from the left): 9 – Moravská Nová Ves-football field, 10, 24 – Moravská Nová Ves-„Padělky od vody", 17 – Mikulčice-„Padělky" („Panské"?), 18, 37 – Mikulčice-„Podbřežníky", 35 – Mikulčice-„Panské", 28 – Mikulčice-house No. 166, 29 – Mikulčice-house No. 559, 1 – Mikulčice-house No. 11, 22 – Mikulčice-„V Břízkách"; 32 – Mikulčice-athletics field. The first sector of hinterland settlement on the Slovak side (from the left): 5 – Kopčany-„Mliečna", 10 – Kopčany-„Seget", 16 – Kopčany-„Za novou Struhou", 15 – Kopčany-the chapel of St. Margita, 2 – Kopčany-„Pri Kačenárni", 17 – Kopčany-„Za Rybníkom", 3 – Holíč-„Hrúdy". The first to second sector of settlement on the Slovak side: 4 – Kopčany-„Medzi Kanálmi". The second sector of hinterland settlement on the Slovak side (from the left): 11 – Kopčany-old school, 14 – Kopčany-„Zadné pole", 12 – Kopčany-Štefánik Square 594, 18 – Kopčany-„Za Záhradami", 9 – Kopčany-farming cooperative, 11 – Holíč „Za Rúžičkú".The localities are numbered according to the individual cadastres; this corresponds to the archaeological topography in the hinterland of Mikulčice stronghold (Škojec 1997, 2005; Baxa et al. 2006) and the mapping of the settlement of the sand dunes in the flood plain of the Morava River (Poláček/Škojec/Havlíček 2003).

development in the past years. The initial concept of Z. Klanica regarding the socially poorer closer sector of the hinterland and the "complete" social structure of the hinterland farther out has been shown to be problematic (cf. Klanica 1987a). New research at the site of the Mikulčice-"Panské"

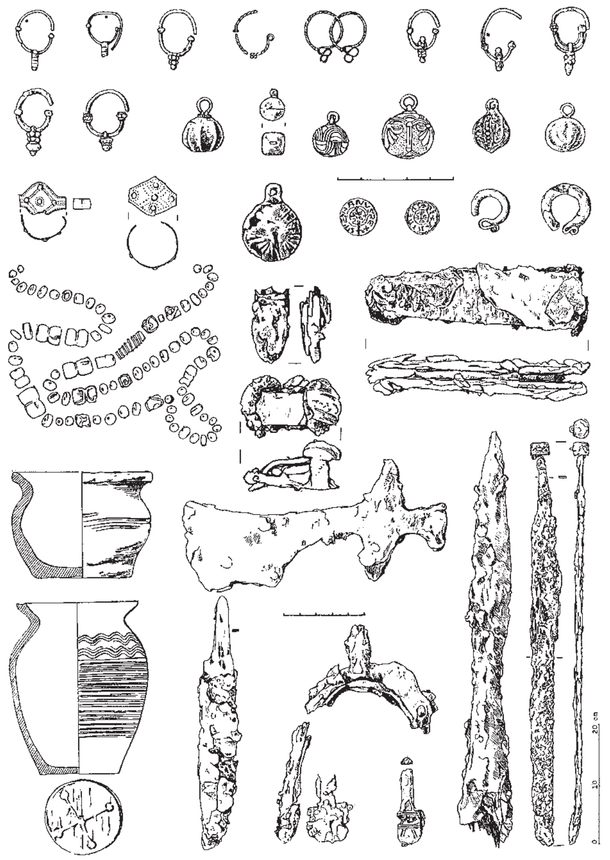

Fig. 18. Mikulčice-„Panské“, burial site from the 9th-11th century. Representative selection of grave findings. According to Poláček 2008b.

burial site (Fig. 18) and in Kopčany near the chapel of St. Margita, i.e. within the "closer" hinterland, show the presence of relatively "rich" burial sites and graves comparable in their basic characteristics with e.g. the necropolis at Prušánky II (Fig. 19) in the more distant hinterland or with the power centre itself. A drawback of this new research is the incompleteness of the uncovered parts of the burial sites, which does not allow for any deeper conclusions (Poláček 2008b).

So far, the nearest sector in the immediate vicinity of the suburb, the settlement in the "Trapíkov" position and the probably associated burial site at Mikulčice-"Virgásky" (originally also termed "Trapíkov") appear to represent the "poorest" parts of the hinterland on the Czech side. On the Slovak side, the corresponding sector is that of the burial site and settlement at Kopčany-"Při Kačenárni". Yet even here, we may have a case of distortion or misrepresentation due to the small extent of excavation and the fragmentation of sources. The possible interpretation of both aforementioned settlements as agricultural hamlets runs against a dearth of reliable sources. For example, there is no evidence of silo-pits, although this may be due to the unfavourable hydrological conditions or rather the proximity of underground water levels. Unfortunately, we lack findings of organic origin especially botanical macro-remains, pollens and animal bones that would enable us to study the economic conditions of these settlements. These categories of findings are usually badly preserved in view of the soil conditions on the low dunes. Similarly, the anthropological material from the burial sites on the drift-sands in the centre's hinterland is characterised by a poor state of preservation, which significantly reduces its predicative properties (Poláček 2008b).

Also, the main criterion used to distinguish the hinterland from the centre – the type of housing structures (earth-houses in the hinterland, surface constructions in the fortified centre and suburb) – may have limitations. Moreover, in the case of the Slovak Kopčany complications arise because of the immediate proximity of earth-houses ("Pri Kačenárni") and the elite milieu (the chapel of St. Margita with the graves of the elite) (Poláček 2001b, 2008b).

According to the results of the latest research, it seems that there is no fundamental difference between the sectors of the Mikulčice hinterland from the aspect of social structure. "Poorer" and "richer" necropolises co-existed, as apparently did similarly differentiated settlements. Naturally, this need not have involved only differences in proprietary conditions, but also e.g. manifestations of various origins and different occupations of the population. One cannot even rule out a reflection of the different age of the localities within the Middle 'Hilfort' period (Poláček 2008b).

The presence of warrior graves in the "rural" burial grounds near the principal centres as well as in the more distant countryside represents a characteristic phenomenon of Old Moravian society in the 9th century. The most probable explanation of this phenomenon is the deployment of the state army in the countryside. Comparison of the relative representation of warrior graves in the necropolises of Prušánky (II) and especially at Mikulčice-“Panské” demonstrates higher proportions than in the case of other Moravian localities (Table 1; see Dresler/Macháček/Přichystalová 2008).

Many unanswered questions that should be the subject of further research remain. For example, an explanation of the incidence of pairs of burial sites that existed at none too great distances from each other, which at least partially temporally overlapped and which demonstrated significant differences in grave equipment. A typical example of this are two near completely explored burial sites at Prušánky (Fig. 26) that are analogical to those e.g. at Nechvalín in the Kyjov district or Rajhrad (Rajhradice) in the Brno district (Klanica 2006; Staňa 2006). It is also important to study in detail the relationship between the burial sites and the corresponding settlements. Unfortunately, this is strongly stigmatised by the unsatisfactory state of settlement research.

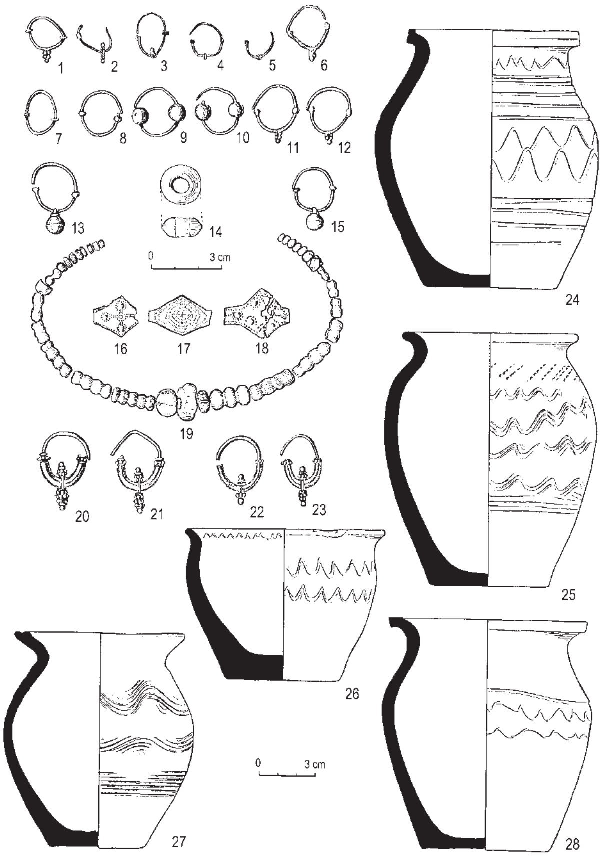

Fig. 19. Prušánky-„Podsedky“, burial sites I and II from the 9th-11th century. Representative selection of grave findings. According to Škojec 2000.

Tab. 1. Comparison of selected Middle ‘Hilfort’ period necropolises in southern and central Moravia on the basis of the number of so-called warrior graves. The numbers in parentheses after the marked site indicate: the total number of graves/the number of men/the number of graves with warrior equipment or riding tackle. According to Dresler/Macháček/Přichystalová 2008; the lines in bold have been added (the data are only approximative and in some cases problematic from the aspect of statistical enumeration).

Site (number of graves/number of men/ number of warriors)	Number of graves/number of graves with warrior equipment or riding tackle (%)	Number of male graves/number of graves with warrior equipment (%)
Pohansko - south bailey (205/28/6)	2.9	21.4
Mikulčice-Klášteřisko (315/76/13)	4.1	17.1
Nechvalín 1 (89/?/7)	7.9	?
Nechvalín 2 (62/?/7)	11.3	?
Prušánky 1 (313/53/7)	2.2	13.2
Prušánky 2 (363/87/25)	6.9	28.7
Nemilany (53/15/10)	18.9	66.7
Velké Bílovice (73/24/10)	13.7	41.7
Rajhrad (564/110/10)	1.8	9.1
Rajhradice (239/44/20)	8.4	45.5
Dolní Věstonice (1296/?/47)	3.6	?
Mikulčice-Panské (113?/30?/15)	**13.3**	**50.0**
Josefov-Záhumenica (178/29/10)	**5.6**	**34.5**

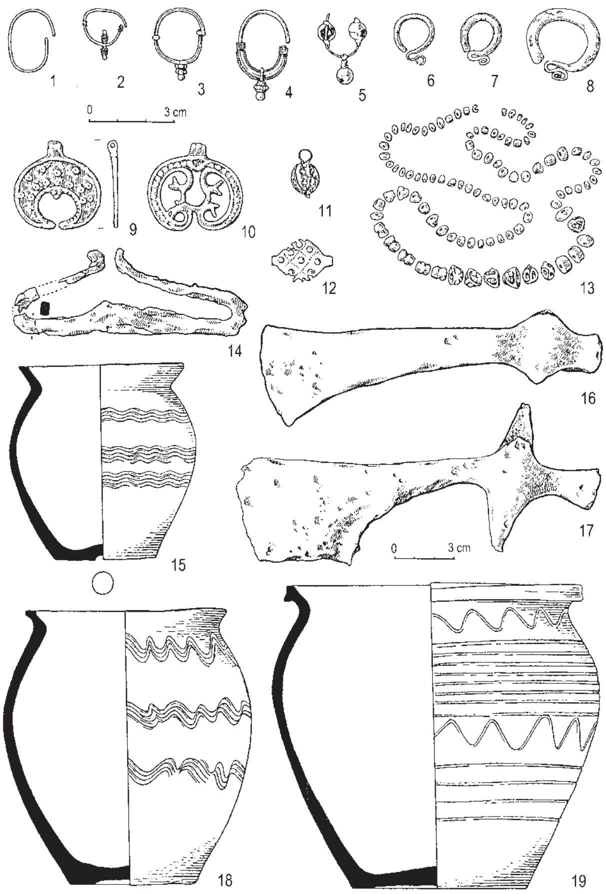

Fig. 20. Josefov-"Záhumenica", burial site from the 9th-11th century. Representative selection of grave findings. According to Škojec 2000 (partly according to Šráčková 1958).

The differences in the demography and state of health of the population that buried its dead at Josefov (Fig. 20; Hanáková/Stloukal 1966) compared to that of Mikulčice stronghold was previously associated with the distinct differences in the living conditions of both groups of inhabitants (Poulík 1985). Current research, though, does not allow such an unequivocal interpretation, as this observation is not repeated at the other burial sites in such a distinctive way. This involved a relatively high percentage of non-adult individuals and a noticeably higher proportion of women among the adult and older individuals. These demographic indicators show that in the case of Josefov, this was not the case of a burial site of a "common" population group.

Closer understanding of the social structure of the hinterland mainly depends on the results of the current detailed archaeological and anthropological evaluation of all the burial sites and settlements cited above. Only then will it be possible to proceed with the overall analysis and summation of all new findings.

4. Burial on the territory of the power centre at Mikulčice and its hinterland

4.1 Moravian burial sites of the 9th century and the first half of the 10th century

Burial sites from the Middle 'Hilfort' period largely represent flat or burial-mound skeleton graves. A special group of burials sites with flat graves is represented by church cemeteries. The change of the burial rites from cremation to burial of the body in Moravia dates to around the year 800. Attempts to associate this phenomenon with the expansion of Christianity are mostly rejected by archaeologists. The cause is sought in the whole complex of social changes. Birituality then occurs almost exclusively in the case of burial-mound necropolises. The horizon of the oldest skeletal graves in Moravia is dated, on the basis of comparisons with the Old Croatian grave findings from Biskupija-Crkvina, to the turn of the 8th and 9th century (Klanica 1990; Měřínský 2006; Ungerman 2006). The Great Moravian graves are organised within the burial sites in irregular groups; irregular rows appear in cemeteries near churches. The set-up of grave pits is diverse (common wooden, less stone tiling, steps, niches etc). A smaller group of burials of important individuals within the circle of power centres was laid in coffins fitted with wrought iron straps. A significant percentage of graves contain gifts and other tokens documenting the lingering influence of pagan traditions. Apart from "urban" burial sites within strongholds and in their vicinity with rich findings of jewellery (of a Byzantine-Oriental character), weapons and evidence of distinctive proprietary differentiation, we find "rural" burial

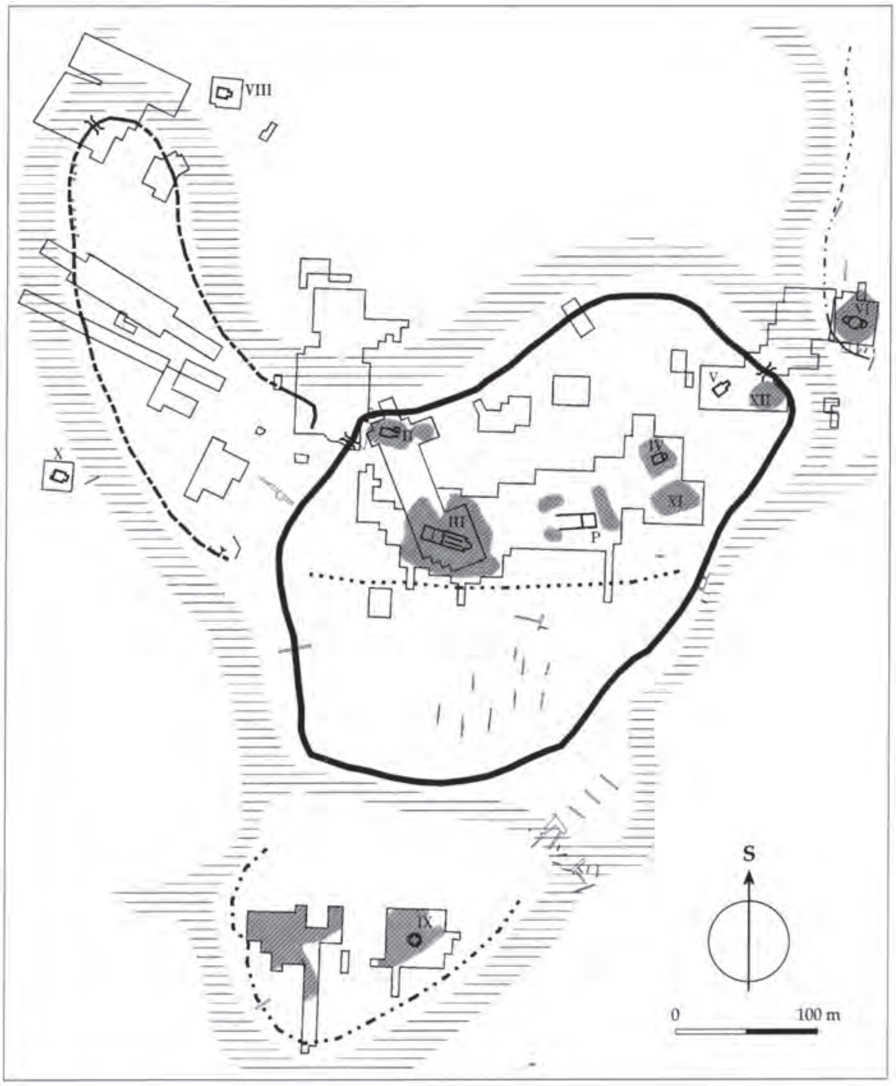

Fig. 21. Mikulčice-Valy. Great Moravian stronghold with designation of the largest burial sites and the most distinctive groups of graves. According to Poláček 2006.

sites with a simpler inventory (especially with ceramics) and with a less distinctive evidence of social stratification. A characteristic sign of rural burial sites is the high proportion of graves with findings and equipment, although overall these are not as ostentatious as in the case of "urban" necropolises (Dostál 1966; Měřínský 1985; Hanuliak 2004).

4.2 Burial in the fortified centre and suburb

Graves from the 8th century have not as yet been discovered in Mikulčice; thus we do not know the way of burial in that period (Klanica 1986). The chronology of the oldest graves at Mikulčice is associated with the beginnings of skeletal burials in Moravia. Based on the analogical findings at Biskupija-Crkvina, the oldest graves in Mikulčice date to the turn of the 8th/9th century (Klanica 1990). These graves, though, are so far sporadic, as in the case of the graves of the whole first third of the 9th century. On the other hand, a great part of the Mikulčice graves belong to the later 9th century. Dating of the youngest graves with characteristic Great Moravian equipment – especially jewellery of the so-called veligradian character – is the subject of much discussion in view of the controversial issue of the enduring typical material culture of the ruling class even after the downfall of Great Moravia in the first half of the 10th century (Třeštík 1991; Dostál 1991).

Most of the graves in Mikulčice were part of the church cemeteries or of simple burial sites (Fig. 21; Poláček/Marek 2005). A smaller number is represented by so-called "settlement"

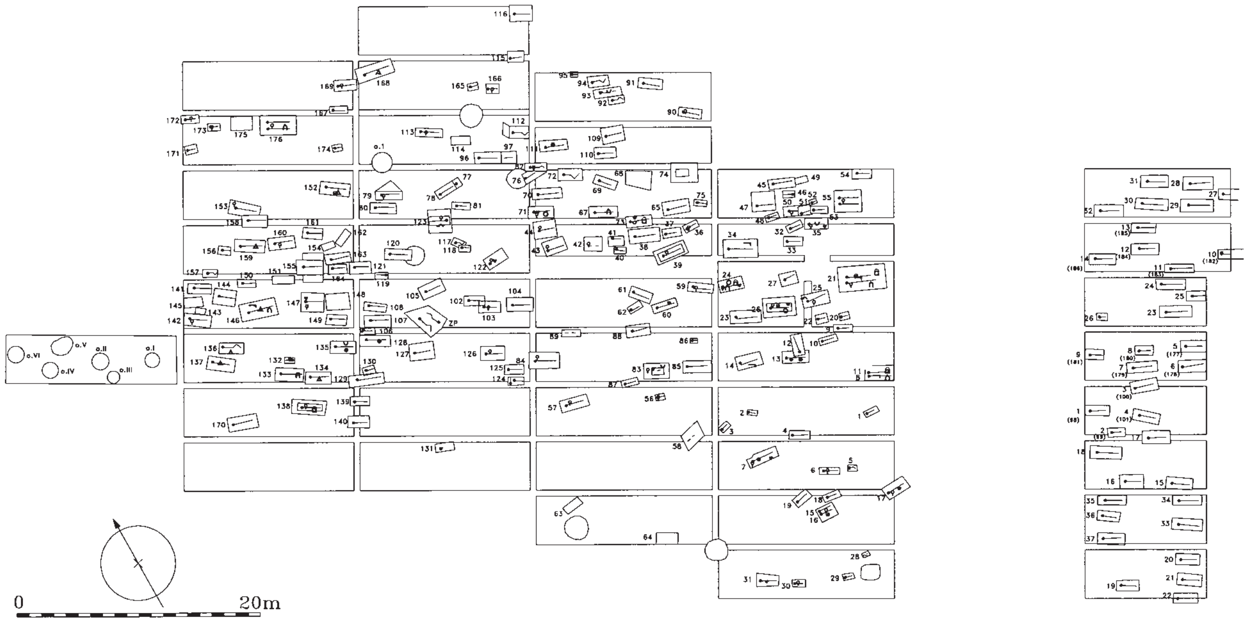

Fig. 22. Josefov-„Záhumenica, burial site from the 9th-11th century. According to Klíma 2007.

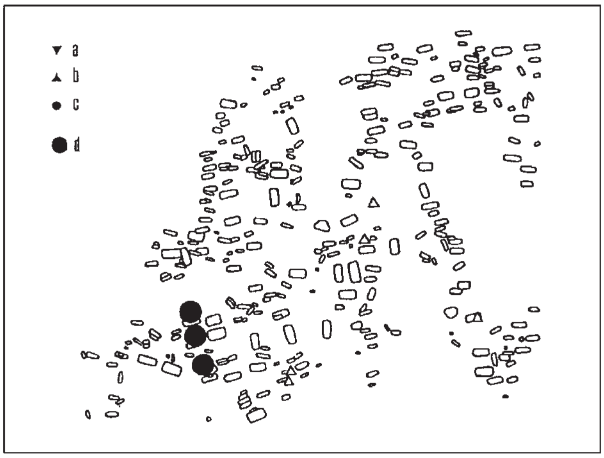

Fig. 23. Prušánky-„Podsedky“, burial site I (9th century). Caption: a – Přemyslid denars, b – Magyar denars, c – temporal rings, d – spurs from the 9th century. According to Klanica 1997.

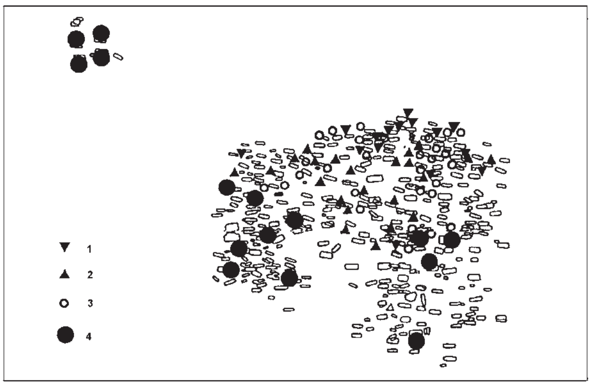

Fig. 24. Prušánky-„Podsedky“, burial site II (9th-11th century). Caption: a – Přemyslid denars, b – Magyar denars, c – temporal rings, d – spurs from the 9th century. According to Klanica 1997.

graves or graves located on the fortifications. The largest and richest necropolises are located near the basilica in the *acropolis* and in the “Kostelisko“ position of the suburb. Both burial sites are characterised by a high intensity of burials, which manifests as the deposition of graves in several layers above each other. Alternation of burial and settlement activities is typical for the areas on the sand dunes (“Těšický les“, “Kostelisko“, “Žabník“; Hladík/Mazuch/Poláček 2008).

Burial sites and graves represent a valuable source of material and information for the complex archaeological and historical understanding of the centre. They indicate the presence of habitation and represent an important stratigraphic element and a valuable chronological base. They attest to the cultural influences on material culture, inform about the social division of the population; they are a source of information regarding the clothing, accoutrements and equipment of the inhabitants of the agglomeration. They provide a unique anthropological material, including all significant historical information.

The wealth and evident attractiveness of grave findings and equipment, though, are in sharp contrast with their current limited testimony. The exploitation of over two and a half thousand graves uncovered thus far in Mikulčice mainly

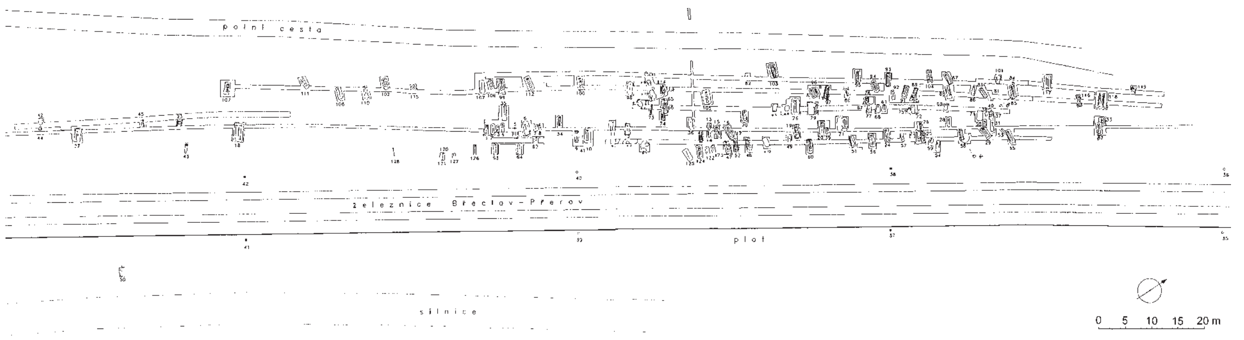

Fig. 25. Mikulčice-„Panské“, burial sites from the 9th-11th century. According to Poláček 2006.

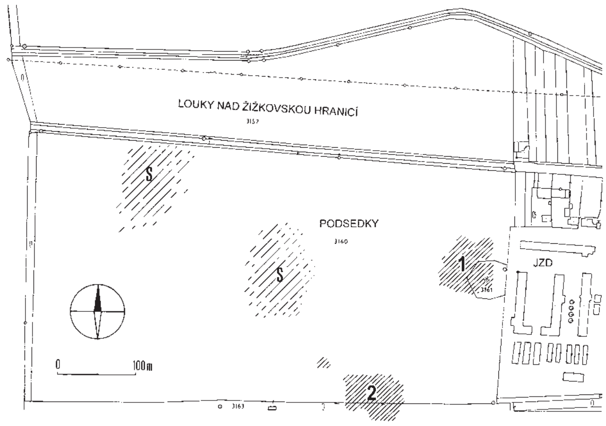

Fig. 26. Prušánky-„Podsedky“, burial site and settlement. Two almost completely explored burial sites (I, II) and two settlements uncovered by surface survey and partially explored archaeologically (S). According to Škojec 2000.

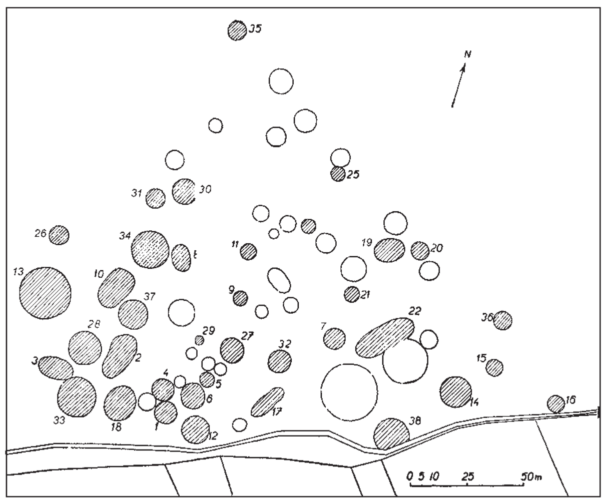

Fig. 27. Skalica-„Háj“ (Slovakia), burial-mound necropolis from the 9th century. According to Budinský-Krička 1959.

runs against the unsatisfactory state of their archaeological processing. So far, the burial sites at the IInd, VIth., VIIth., VIIIth church and XIIth church, as well as the burial site on the “Kostelec” position (“Klášteřisko”) have been published (see Table 2). Furthermore, certain groups of findings from individual graves or groups of graves have also been made public – e.g. those from the hypothetical XIth church, from the IIIrd church or from the “Žabník” position in the suburb as well as other important grave complexes, e.g. tomb XVI with grave 580 in the IIIrd church or grave 821 near the “XIth church”. Yet a larger part of the graves lacks critical source processing and publication so far.[15]

Compared to the state of archaeological evaluation, the anthropological processing of the burial sites today is quite further advanced: most of the main Mikulčice burial sites have already been subjected to basic anthropological analysis (see Table 2).

4.3 Burial in the hinterland

For greater clarity, we present a brief archaeological characterisation of the most important burial sites of the 9th-10th century in the economic hinterland of Mikulčice hilfort:

- Mikulčice-”Virgásky“ (originally “Trapíkov”). The Czech side of the agglomeration. Distance from the centre 1.3 km. Salvage research 1957-1958. 29 Great Moravian skeletal graves. Exploration of a closely unspecified section of

15 Summary of burial sites and graves et Mikulčice see Poláček/Marek 2005.

the burial site. Relatively low number of graves with findings and equipment (41%; may be affected by the character of the excavation); no weapons. “Poor“ Great Moravian rural burial site. Corresponding settlement explored at a distance of 250-500 m on the “Trapíkov“ position (earth-houses with stone oven in the corner) (Kostelníková 1958; Poláček/ Rutar 2004).

- Mikulčice-“Panské“ (Fig. 25). The Czech side of the agglomeration. Distance from the centre 3.5 km. Research 1999-2000. Of the 128 skeletal graves, a majority of Great Moravian origin, and approximately 13 of Late ‘Hilfort’ period origin (11^{th} century). Exploration of a closely unspecified part of the burial site from the 9^{th}-11^{th} century. Majority of Great Moravian graves with findings and equipment (84%); significant representation of warrior graves with arms and spurs (13%; see Table 1); short sword - sax in grave No.103. “Richer“ Great Moravian rural burial site with connections to Late ‘Hilfort’ period burial (on the southern and south-western side). Corresponding settlement known from new excavations of the “Podbřežníky” position, at a distance of approx. 300 m (Poláček et al. 2000, 2001).
- Josefov-“Záhumenica“ (Fig. 22). The Czech side of the agglomeration. Distance from the centre 7 km. Excavation 1957-1962. 171 Great Moravian skeletal graves (with the remains of 178 individuals) and 38 Late ‘Hilfort’ period graves. Exploration of practically the whole older section of the burial site from the 9^{th}-10^{th} century, while its Late ‘Hilfort’ period section from the 11^{th} century represents only a smaller part. The greater majority of the graves contained findings and equipment (74%); graves with ceramic vessels are characteristic. On the other hand, a minority of warrior graves (with axes or spurs; 6%; see Table 1). “Poorer” rural Great Moravian burial site with connections to Late ‘Hillfort’ burial (on the south-eastern side). Another two settlements known from the surface survey, at a distance of 400 to 900 m (Klíma 2007 with lit.; Škojec 2000, 2005).
- Prušánky-“Podsedky“, burial site I at a distance of 150 m from the Prušánky II burial site (Fig. 23, 26). The Czech side of the agglomeration. Distance from the centre 9.5 km. Excavation 1975, 1978-1980, 1983. 313 Great Moravian, predominantly skeletal graves (traces of cremation pit graves in the southern section of the burial site). Most of the necropolis has been explored. Approximately 70% of the graves have findings and equipment with a high proportion of ceramic vessels; in contrast, spurs and arms found only in 7 graves (2.2%). “Poorer“ rural Great Moravian burial site. Two Great Moravian settlements with earth-houses at a distance of 200 and 400 m (Klanica 2006).
- Prušánky-”Podsedky“, burial site II at a distance of 150 m from the Prušánky I burial site (Fig. 24, 26). The Czech side of the agglomeration. Excavation 1979-1983, 1985, 1988. Approx. 363 Great Moravian and Late ‘Hilfort’ period skeletal graves (minimal number of Late ‘Hilfort’ period graves 70); one cremation grave mentioned. Exploration of practically the whole burial site from the 9^{th}-11^{th} century with an isolated group of 12 “rich” Great Moravian graves. Proportion of graves with findings and equipment smaller in comparison with the first Prušánky burial site (50% on estimate); representation of graves with spurs and arms higher on the other hand (at least 11%); a sword in grave 229. “Richer” rural Great Moravian with connections to the Late ‘Hilfort’ period burial (on the northern side). Known and partially explored two Great Moravian settlements with earth-houses and other objects in the vicinity of the burial site (100-350 m) (Klanica 2006).
- Kopčany-“Pri Kačenárni“. The Slovak side of the agglomeration. Distance from the centre 1.9 km, distance from the chapel of St. Margita 300 m. Excavation 1960-1964. 61 Great Moravian skeletal graves. Exploration of the more closely undefined section of the burial site. Remarkable low proportion of graves

Table 2. Overview of the main burial sites and larger groups of graves in the Mikulčice stronghold with reference to their archaeological and anthropological processing.

Burial site	No. of graves	Position	Archaeology	Anthropology
IInd church	236	acropolis	Poulík 1957	Stloukal 1963
IIIrd church	564	acropolis		Stloukal 1967
IVth church	106	acropolis		Stloukal 1969
VIth church	205	acropolis	Poulík 1963, Profantová 2003	Stloukal 1964
VIIth church	16	suburb		
VIIIth church	26	suburb	Kouřil 2008	Velemínský/Brůžek 2008 (preliminarily)
IXth church	150	suburb	Měřínský 2005 (preliminarily)	
Xth church	11	suburb		
hypothetical XIth church	81	acropolis		Stloukal 1981
hypothetical XIIth church	85	acropolis	Kavánová 2003	Stloukal/Vyhnánek 1998
Group NW from the palace	17	acropolis		
Group E of the palace	25	acropolis		
Kostelisko	415	suburb		Velemínský et al. 2005
Žabník	85	suburb	Bartošková in print	Bartošková/Stloukal 1985
Kostelec (Klášteřisko)	317	suburb	Klanica 1985b	Stloukal/Hanáková 1985
Total	2339			

with findings and equipment (26% – may be affected by the character of the research); relatively high proportion of warrior graves with arms and spurs (6.6%). "Poorer" Great Moravian burial site, apparently affected by the proximity of the centre of power. Corresponding settlement with earth-houses and other objects in the immediate vicinity; here, other "settlement" graves (Kraskovská 1965, 1969).

- Skalica-"Háj" (Fig. 27). The Slovak side of the agglomeration. Distance from the centre 12 km. Excavation 1922-1923 and 1943-1944. Seventy-three Great Moravian graves in 38 burial-mounds, predominantly of the skeletal type and only some of the cremation type, discovered during the second phase of research. Exploration of nearly one half of the burial site. A great proportion of graves with findings and equipment (approx. 80%); the addition of vessels into the graves, a great proportion of warrior graves with arms and spurs (18%; 1 grave with sword) is characteristic. "Richer" rural burial-mound biritual burial site from the Great Moravian period (Budinský-Krička 1959).

The aforementioned burial sites represent an important source of material for understanding the social structure of the settlement of the Mikulčice centre hinterland. Of course, the state of basic source processing, analysis and publication of this material remains highly disproportionate. The burial complexes at Josefov, Mikulčice-"Panské", Mikulčice-"Virgásky" and Kopčany are currently well processed and analysed. The new publication regarding the burial sites at Prušánky from Z. Klanica (2006) lacks both an analysis and a comparison of both necropolises from the aspect of the social structure. The basic precondition for further understanding is the critical study of source material from all the necropolises, its complex archaeological and anthropological analysis and a mutual comparison of these within the study of the settlement structure and settlement development of Mikulčice centre and its hinterland (Poláček 2008b).

The common characteristic of the aforementioned "rural" burial sites is the high proportion of graves with findings and equipment (often as much as 70-80%), with lower figures demonstrated in the burial sites near the stronghold, probably due to the influence of the church institutions from the centre. A significant part of these findings consist of gifts, as a remnant of pre-Christian cult practices (Měřínský 1985).

Another characteristic phenomenon is the relatively frequent incidence of warrior graves equipped with axes (less frequently with spears or arrow tips), and sporadically swords (Table 1). Swords are thus far represented only in the "richest" rural necropolises, and always in only a single grave (Prušánky II, Mikulčice-"Panské", Skalica-"Háj"). These warriors apparently represented part of the permanent military reserves, which were recruited from the free inhabitants of the village commons (see Dresler/Macháček/Přichystalová 2008). The only burial site, where arms have as not yet been discovered, is that of Mikulčice-"Virgásky", the burial site closest to the centre. This locality may be considered to be the "poorest" burial site in the centre's hinterland, although this may only be the case of a phenomenon influenced by the small number of explored graves.

5. Conclusion and prospects

Understanding of the structures of the Old Moravian society is limited by the character of the archaeological sources themselves, the state of processing and analysis of old excavations from the second half of the 20th century, as well as the state of theoretical research. This relates to both burial sites and settlements. Both groups of sources reflect the social structure in different and specific ways. In this sense, cases where for the given uncovered burial site we have at our disposal the corresponding explored settlement are optimal for our work. This especially applies to rural settlements, where both components can be more easily and unequivocally demarcated in space. The situation in the case of settlement agglomerations, such as Mikulčice stronghold, that consist of mutually inter-mingled settlement and burial site complexes is significantly more complicated. Here, appreciation of the link between the population group inhabiting a certain settlement and its burial site is difficult. A straight-forward interpretation, e.g. that the burial site in the *acropolis* served the inhabitants of the *acropolis* or that the burial site in the suburb served the inhabitants of the suburb, is hardly possible. Yet, this complicated temporal-spatial relationship conceals an important information potential and a source of deeper understanding. Application of this source is a question for the future, as this is subject to the archaeological and anthropological processing of all burial sites of the settlement complex, and their comparison and setting within the general settlement development of the given locality.

An important component of today's socially-oriented archaeological study of the Moravian society in the 9th century is the search for and verification of criteria for the identification of individual social classes and groups. Graves and burial sites represent an important archaeological source for the understanding and identification of the social structure of the society. Their evidence, though, is not simple or unequivocal, as apart from the social structures themselves, they reflect a number of other influences – religious, cultural, customary, chronological etc.

In the case of Mikulčice, it is clear that among the 2500 graves explored thus far, graves belonging to the highest social elites of that time are also present. Their presence is already given by the mere existence of a power centre of paramount importance. Strong fortifications, the palatial construction, numerous churches and other walled structures, rich graves with findings of arms and luxurious objects – all this is a manifestation of a significant concentration of political power. It is probable that the graves within the churches or on the main church premises belonged to members of the ruling Mojmír dynasty.

The social interpretation of burial sites in the hinterland of the centre is easier due to the unequivocal spatial demarcation of the burial site complexes. The problem again is the general processing and analysis of the burial sites. Although several necropolises are currently processed or prepared for publication, comprehensive source materials are available for only three complexes

– two flat burial sites at Prušánky and the burial-mound site at Skalica (Klanica 2006; Budinský-Krička 1959). Though the link between the burial site and the corresponding settlement is known or surmised in a number of cases, the state of research of the settlements is generally insufficient. Thus far, we have at our disposal only the non-processed and analysed uncovered smaller sections of two settlements at Prušánky-”Podsedky“(corresponding to two burial sites on the position of the same name), and the results of new exploration of the settlement at Mikulčice-”Podbřežníky“ (corresponds most probably to the burial site on the “Panské” position). In such a situation, any conclusions regarding the social structure of the Mikulčice hinterland may only be working hypotheses.

Earlier evaluation of the social structure of the Mikulčice centre hinterland was based on the comparison of the “internal” and “external” sectors of the hinterland settlement. The internal sector was characterised as socially relatively poor. It was represented on the one hand by localities at the edge of the flood plain on the Czech side of the Morava River, and on the other by the settlement and burial site of “Při Kačenárni” in Kopčany on the Slovak side. In contrast, the external sector was designated as being richer, demonstrating a “complete social structure” (Prušánky II, Skalica). In contrast to the necropolises in the immediate vicinity of the centre, where burial ends coincidentally with the downfall of the power centre during the first half of the 10th century, some of the burial sites of the hinterland existed further into the 11th-12th century (see Klanica 1987a).

Today, following the acquisition of new material from other settlements and burial sites, the situation outlined above changes: it is clear that in all the sectors studied, approximately at a distance of 10 km from the centre, both “rich” and “poor” burial sites occur side by side. The original “internal” sector on the western edge of the flood plain is represented by the newly explored burial site at Mikulčice-”Panské”, with a significant proportion of graves with arms, the discovery of a sax, as well as of silver and gold-plated buttons with moulded decorations, all typical of the centre itself.

If one may still speak of a “poor” sector of the settlement, then this may today apply only to the nearest surroundings of the suburb, i.e. the settlements on the sand dunes in the flood plain of the Morava River. This would be supported by the very frugal equipment of the graves in the Mikulčice -”Virgásky” (“Trapíkov“) position or the burial site on the “Pri Kačenárni” position near Kopčany. The discovery of earth-houses in both these positions would appear to support the thesis regarding the agricultural settlements situated in the closest sector, directly contingent with the suburb. Naturally, even this image is “complicated” by new facts. A Great Moravian church with burials that contain typical veligradian jewellery and even one simple gold earring has been identified in the immediate vicinity of the settlement with earth-houses at Kopčany. This is evidently a noble milieu similar to the “Valy” stronghold near Mikulčice itself. All this thus suggests that all the sectors of the hinterland had their own, relatively varied social structure. Moreover, its interpretation is complicated by the specific predicative properties of archaeological sources (Poláček 2008b).

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Anthropological and epidemiological characterization of Great-Moravian population in connection with the social and economic structure

Reliable Sex Determination Based on Skeletal Remains for the Early Medieval Population of Great Moravia (9^{th}-10^{th} Century)

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This paper discusses and proposes a reliable sexing technique from an human cranial material for early medieval central European population. The processed discriminant function analysis (DFA) is very accurate and is a population specific tool for sex determination (or exactly estimation). The application of so-called primary and secondary sex diagnosis is necessary and concern a large sample of three Great Moravian graveyards. Only skeletons with preserved hip bone and cranium were employed (n=332). The secondary sex diagnosis uses 12 linear cranial variables commonly employed in other studies using DFA. A set of 9 DFA specific for the studied medieval central European population is proposed. The accuracy of DFA varies from 80,3% (with 4 variables) to 86,1% (with 5 variables). We also carried out a reliability test of the DFA in a small sample 28 skulls whose sex was estimate using a primary sex diagnosis tool. The error rate is in agreement with the observed classification accuracy, around 80%. The proposed DFA can be used in the field for a quick and preliminary sexing of cranial remains or in absence of the pelvic bones in the context of Great Moravian region only (without the influences of asian ethnic groupes).

Key words: Early Medieval population – Great Moravia – sex determination – secondary sex diagnosis – cranial variables

1. Introduction

Sex determination plays a key role in all osteological studies (e.g. Bass 1987; Krogman/Işcan 1986; Buikstra/Ubelaker 1994) and the determining details such as sex, age at death, height or population affinity are the first, basic tasks of skeleton identification (Scheuer 2002). Information on sex affiliation is not only important for bio-archaeological studies of past populations, but also for the archaeological and funeral interpretation of burial sites. Inconsistency in the representativeness of the skeletal group according to sex in relation to the natural mortality in past populations is the subject of palaeodemographic studies. Information on sex affiliation also has an important role in palaeo-epidemiological studies and for assessing the incidence of disease or injuries in populations of the past, indirectly including an appraisal of living conditions, of work activities or of the quality of nutrition in past human populations (e.g. Cohen/Bennett 1998; Grauer/Stuart-Macadam 1998).

It is important to emphasise that any sex determining approach or technique used in the field on the basis of personal and subjective experience can replace the real methods used in the laboratory. Nevertheless, it is always

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recommended to document during excavations (photographs and written records) those parts or details of the skeleton which provide information on the sex of the individual, because there is always a risk of damage during their exposure to climatic conditions, or during the removing phase either when cleaning the skeleton in the laboratory processing.

The direct use of measurements taken from the skeleton or simple methods such as indexes (Sullivan/Hall 1981) does not guarantee reliable sex diagnosis (Bruzek 1991). Thus the only objective tool for determining the sex of skeletal remains is discriminant function analysis (DFA), although discriminant functions proposed for the skull, mandible and long limb bones (e.g. Krogman/Iscan 1986; Sjøvold 1988), are population specific. This fact has been pointed out by a number of researchers (already e.g. Henke 1977; Novotný 1981 and more recently e.g. Albanese/Cardoso/Saunders 2005; Işcan et al. 1998), who maintain that discriminant functions only apply to the population for which they were proposed or calculated. In order to correct for different conditions of use, these authors propose modifying the discriminant function's sectioning point, however this requires the availability of a sufficient number of skeletons (bones) of known sex from the new population. This seemingly paradoxical condition appears totally unusable for archaeology, i.e. for past populations. The pitfall for users of discriminant functions, represented by the size or format of measurements, is the source of significant inaccuracy, interpretative errors and conflicting results (Bruzek/Murail 2006).

All morphological methods used for sex determination are based on the existence of sexual dimorphism in the skeleton. Sexual dimorphism is caused by the existence of different sex chromosomes and the biological development of males and females. For this reason it is not possible to determine the sex of non-adult individuals with necessary accuracy and reliability as during ontogeny the degree of sexual dimorphism in the skeleton is very low. Nevertheless, the absolute accuracy in sex determination for adult individuals is impossible. The reason is that the existence of numerous anomalies arise during the course of sex differentiation and development of individuals. Another factor is the continuous variability in the development of sex characteristics that contrast with alternative nature of the two sex categories.

With sex diagnosis methods we must therefore distinguish accuracy and reliability, which are varying inversely. This means that increase in accuracy implies decrease in reliability of the sexing and vice versa. The higher accuracy in sex determination results is achieved by using the hip bone, whose sexual dimorphism is stable for all human populations and the methods are reliable with respect of a choice of optimal set of variables from all morpho-functional segments of the pelvis. In the contrary, methods based on «extra-pelvic» variables of the skeleton are specific for a considered population. Their degree of sexual dimorphism is a limiting factor for successful sex determination.

For these reasons, methods proposed for determining sex from the skeleton are not, and cannot be absolutely accurate. There is a generally accepted statement that a single characteristic cannot lead to a reliable result. The accuracy of morphological methods for determining sex is estimated at 80 percent or more ; yet the reliability of these results is sometimes lower. However, the accuracy and reliability of the sexing in anthropology and archaeology must be identical that the arbitrarily set limit of 95% that is a necessity in forensic anthropology (Scheuer 2002; Bruzek/Murail 2006). A high degree of inaccurate sex diagnosis (misclassifications) has a significant affect on taxonomic, archaeological and biological interpretations and in such cases we must look for other explanations for methodological errors (Bruzek 1996). Sexual dimorphism in body size is variable, difficult to assess and is often a random phenomenon, being sensitive to changes in living conditions, as well as changes of population's genetic structure. These factors are then necessarily reflected in the morphometric characteristics of the human skeleton.

The recommendation for correct and reliable sex determination is primary and secondary sex diagnosis (Murail/Bruzek/Braga 1999) which was successfully tested on an archaeological population of known sex from Spitalfield (Molleson/Cox 1993). This method consists of three stages. In the first stage we determine the primary sex diagnosis of individuals on the basis of the pelvic bone, in those cases where the pelvic bone has been preserved. We can exploit the fact that reliable methods based on pelvic characteristics are not population specific (e.g. Bruzek 2002). In the second stage, we calculate DFA and posterior probability based on extra-pelvic measurements in the group of individuals whose sex was determined in the first stage. The specific DFA thus acquired are used to determine the sex of those individuals whose pelvic bone did not survive or whose sex could not be determined. Proposed population specific discriminant functions for various parts of the skeleton, where the sex of skeletal remains was determined in the primary stage using the pelvis, have been used in numerous studies (e.g. Bocquentin 2003; Dittrick/Suchey 1986; Murail 1996; Stojanowski 2003; Wrobel/Danforth/Armstrong 2002). Although the computation of discriminant functions is now very easy thanks to computer technology and software packages, this step must still be preceded by primary sex diagnosis based on the pelvis, which is not always possible in practice.

The aim of this contribution is to offer a suitable tool for determining the sex of not only isolated human skeleton finds, but also of extensive burial sites, prior to detailed laboratory processing. The proposed discriminant functions for skull measurements are only applicable for Central European populations of the 9th to 12th century. This contribution only looks at the skull, which is often the part of the skeleton most closely examined by field workers. This method thus aims to contribute to the relatively quick and reliable determination of the sex of adult individuals. The chosen approach can be applied to other parts of the skeleton, which will be the subject of further contributions.

2. Material and methods

Material – The skeletal remains from three Great Moravian burial sites were used for this study. Two of the burial sites are part of the Mikulčice power centre settlement – this being the second burial site at the three nave basilica on the grounds of the castle with 569 graves (Stloukal 1967) and the burial site at Kostelisko

Table 1. List of pelvic variables. The measurements selected for the probabilistic sex diagnosis (DSP) after Murail et al. 2005. Letter M refers to Martin measurements' codes (Bräuer 1988).

Variables	Description	Reference
PUM (M14)	Acetabulo-symphyseal pubic length	Bräuer, 1988
SPU	Cotylo-pubic breadth	Gaillard, 1960
DCOX (M1)	Pelvic length	Bräuer, 1988
IIMT(M15.1)	Greater sciatic notch height	Bräuer, 1988
ISMM	Ischium post-acetabular length	Schulter-Ellis et al. 1983
SCOX (M12)	Iliac breadth	Bräuer, 1988
SS	Spino-sciatic length	Gaillard, 1960
SA	Spino-auricular length	Gaillard, 1960
SIS (M14.1)	Cotylo-sciatic breadth	Bräuer, 1988
VEAC (M22)	Vertical acetabular diameter	Bräuer, 1988

Table 2. Linear measurements used for secondary sex diagnosis. Ab. = Abbreviation of Measurements after Martin (Bräuer 1988), in parantheses after Howells (1996) ; CAP=cranial anthropological points.

Abbreviation of Measurements	Measurements	Cranial Measure-ments	Definition
M1 (GOL)	Maximum Cranial Length	g-op	The distance of Glabella (g) from Opisthocranion (op) in the mid sagittal plane measured in a straight line
M5 (BNL)	Cranial Base Length	n-ba	The direct distance from nasion (n) to basion (ba)
M8 (XCB)	Maximum Cranial Breadth	eu-eu	The maximum width of the skull perpendicular to the mid sagittal plane wherever it is located with the exception of the inferior temporal line and the immediate area surround the latter (i.e. the posterior roots of the zygomatic arches)
M9 (WFB)	Minimum Frontal Breadth	ft-ft	The direct distance between the two frontotemporale
M12 (ASB)	Maximum Occipital Breadth	ast-ast	the direct distance between the two asterion
M17 (BBH)	Basion Bregma Height	ba-b	The direct distance from the lowest point on the anterior margin of the foramen magnum, basion (ba), to bregma
M40 (BPL)	Basion Prosthion Length	ba pr	The direct distance from basion (ba) to prosthion (pr)
M45 (ZYB)	Bizygomatic Breadth	zy-zy	The direct distance between each zygion (zy), located at the most lateral points of the zygomatic arches
M47 (-)	Facial Height	n-gn	The direct distance from nasion (n) to gnathion (gn)
M48 (UFHT)	Upper Facial Height	n-pr	The direct distance from nasion (n) to prosthion (pr)
M51 (OBB)	Orbital Breadth	d-ek	The laterally sloping distance from dacryon (d) to ectocon-chion (ec)
M52 (OBH)	Orbital Height		The direct distance between the superior and inferior orbi-tal margins

in the sub-castle with 425 graves (Velemínský 2000; Velemínský et al. 2005). The third burial site – Prušánky I – in the Mikulčice centre hinterland, provided approximately 330 graves (unpublished data). All the burial sites date to the 9-10th century. Only 216 adult individuals from the Mikulčice-Valy (castle) burial site and 116 adult individuals from the Kostelisko burial site could be used for sex determination. A criterion for selection was the preservation of the hip bone or a part thereof. A small sample (n = 28) of adult individuals from the Prušánky I burial site with preserved hip bones and skulls were used as a reliability test of the proposed discriminant functions.

Methods – (1) primary sex diagnosis is based on the PSD program (Murail et al. 2005). This involves the calculation of posterior probability for an unknown hip bone, which classifies it as either male or female according to the chosen level of significance. The database contains more than 2 000 hip bones for individuals of known sex from various populations on four continents, dating from the 18th to 20th century. Sex is determined by comparing the specimen‘s measurements to the database and computing the probability it is a female or a male from any combination of four variables among ten. The following measurements were taken from the hip bones (Table 1). Sex was allocated using the PSD program only if posterior probability was equal to, or higher, than 0.95.

(2) The secondary sex diagnosis of skulls uses 12 linear measurements according to Martin (Bräuer 1988) and Howells (1996) as

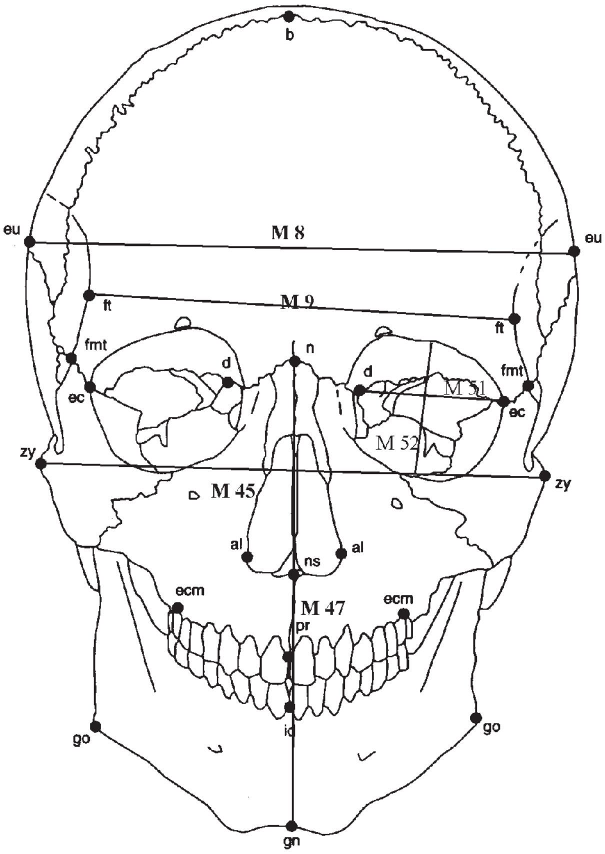

Fig. 1a. Cranial measurements and anthropological points – frontal position.

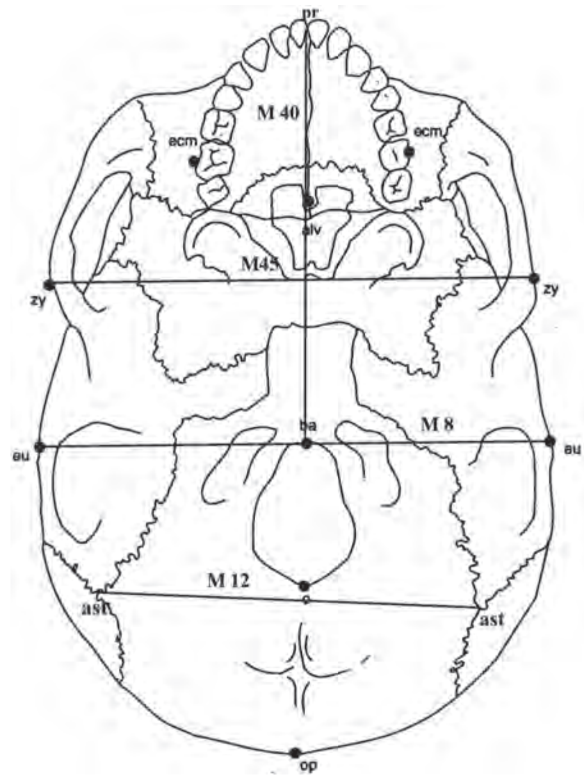

Fig. 1c. Cranial measurements and anthropological points – inferior position.

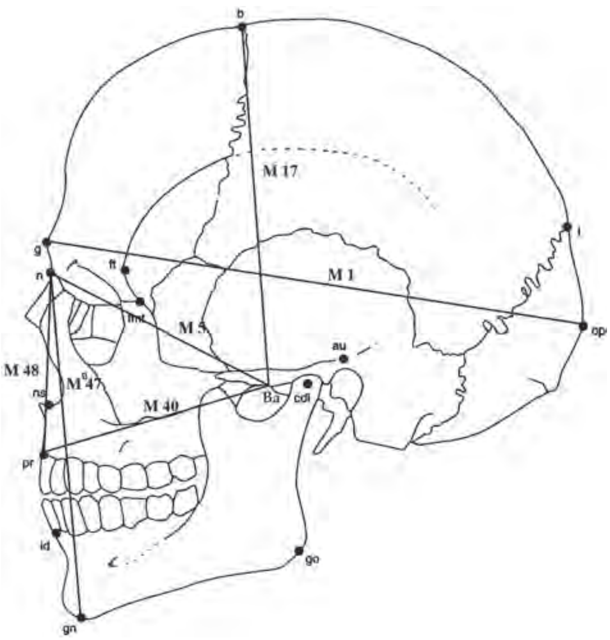

Fig. 1b. Cranial measurements and anthropological points – lateral position.

presented in Table 2 (measurement – abbr. of anthropometric points – definition of measurements – see Fig. 1a-c).

Selection of discriminant functions – The selection of measurements for the calculation of discriminant functions was subject to three criteria:

a) measurements that have proven to be successful by other authors in discriminant analyses (Hanihara 1959; Kajanoja 1966; Henke 1974; Giles/Elliot 1963; Šefčáková/Mizera/Thurzo 1999; Franklin/Freedman/Milne 2005),
b) a list of standard cranial measurements taken by the Anthropological Department of the National Museum in Prague,
c) good condition of skeletal remains to be processed.

The computation of discriminant functions and other statistics was carried out using Statistics 7.1. and MS Excel 2003 software.

Table 3. Results of primary sex diagnosis of specimens from the Great Moravian burial sites in Mikulčice based on the pelvis (on the hip bone).

	PSD Nonaplicable	PSD M	PSD F	PSD M & F	PSD ?	PSD total
Mikulčice - castle n=216 (100%)	19 (8,8%)	106 (49,1%)	56 (25,9%)	162 (75%)	35 (16,2%)	197 (91,2%)
Mikulčice - sub-castle n=116 (100%)	48 (41,4%)	22 (19%)	26 (22,4%)	48 (41,4%)	20 (17,2%)	68 (58,6%)
Mikulčice - total n=332 (100%)	67 (20,2%)	128 (38,6%)	82 (24,7%)	210 (62,3%)	55 (16,6%)	265 (79,8%)

Table 4. Summary statistics of cranial variables in the Greath Moravia skeletal sample employed in secondary sex diagnosis (discriminant function analysis).

	Males					Females							
	n1	x	Min	Max	s	n2	x	Min	Max	s	t-test	p	F-test
M1	91	187,9	171	204	6,5	54	179,6	165	193	6,0	8,260	***	1,158560263
M5	80	104,3	91	116	4,7	48	97,5	90	110	3,6	6,758	***	1,716276895
M8	88	142,0	130	155	5,3	54	138,2	128	150	5,2	3,838	***	1,034404893
M9	93	99,9	88	126	5,1	59	96,1	88	103	3,7	3,775	***	1,876589518
M12	82	111,4	100	122	5,2	47	108,4	98	124	5,0	2,995	**	1,105530994
M17	86	137,7	126	160	5,5	52	131,3	122	143	4,5	6,483	***	1,490536199
M40	74	99,0	84	113	5,7	47	93,4	82	105	5,1	5,580	***	1,25439356
M45	72	133,6	101	144	5,8	47	125,8	104	136	6,1	7,817	***	0,895956344
M47	79	120,8	105	136	7,0	49	111,6	98	123	6,4	9,236	***	1,20171464
M48	81	72,6	63	82	12,7	51	67,5	58	77	4,1	6,337	***	9,402885561
M51	81	43,7	37	105	9,7	49	40,5	36	44	2,2	3,202	**	20,2082046
M52	81	35,4	22	102	10,9	49	32,9	28	37	2,0	2,522	*	29,07832265

M = abbreviation of measurements after Martin (Bräuer 1988)
p = probability level
* = 0,05 (value >1,960),
** = 0,01 (value > 2,576),
*** = 0,001 (value > 3,290)

The group of specimens from the Mikulčice burial sites was used to propose discriminant functions for the skull and those from the Prušánky burial site were used as a test sample to verify their validity.

3. Results

Given the good condition of hip bones (Table 3), primary sex diagnosis (PSD) was carried out on 197 skeletons from the second Mikulčice-Valy burial site, of which sex was determined for 162 individuals. Of the 68 skeletons with hip bones from the Kostelisko burial site, sex was determined for 48 individuals. Sex was thus determined with a probability of 95% or higher for a total of 210 individuals from Mikulčice based on hip bones. Skeletons with reliable sex diagnosis based on hip bones will be used in secondary sex diagnosis to calculate discriminant analyses based on the skull. The testing sample from Prušánky allowed the

Table 5. Summary statistics of discriminant function analyses (DFA) of cranial variables in pooled sample of Greath Moravian cemeteries from Mikulčice.

Diskriminant Funktion (DF) N°	Number of Variables	Wilk's lambda	F-statistics	Probability	Variables Employed
DFA 1	4	0.582	17.930	0.000	M 1, M 40, M 45, M 48
DFA 2	5	0.549	16.266	0.000	M 1, M 5, M 8, M 45, M 48
DFA 3	4	0.562	19.690	0.000	M 1, M 5, M 8, M 45
DFA 4	3	0.556	27.716	0.000	M 1, M 17, M 45
DFA 5	4	0.594	17.562	0.000	M 1, M 8, M 45, M 52
DFA 6	5	0.524	19.784	0.000	M 1, M 5, M 8, M 12, M 17
DFA 7	3	0.621	26.055	0.000	M 1, M 8, M 17
DFA 8	4	0.577	18.858	0.000	M 1, M 8, M 45, M 48
DFA 9 (a)	5 (b)	0.511	16.636	0.000	M 5, M 17, M 45, M 47, M 51

(a) stepwise DFA of 12 variables
(b) number of variables entered
(M) abbreviation of measurements after Martin (Bräuer 1988)

Table 6. Secondary sex diagnosis – sexing accuracy for discriminant function 1-9 for the pooled sample of Great Moravia skulls (Mikulčice-Valy and Mikulčice-Kostelisko Cemeteries).

Discriminant Function (DF) N°	Number of Variables	Variables	Males		Females		Correctly Assigned	
			N	%	N	%	N	%
DFA 1	4	M 1, M 40, M 45, M 48	55 / 65	84.6	32 / 40	80.0	85 / 105	82.9
DFA 2	5	M 1, M 5, M 8, M 45, M 48	54 / 65	83.1	32 / 40	80.0	86 / 105	81.9
DFA 3	4	M 1, M 5, M 8, M 45	55 / 66	83.3	32 / 40	80.0	87 / 106	82.1
DFA 4	3	M 1, M 17, M 45	57 / 67	85.1	33 / 41	80.5	90 / 108	83.3
DFA 5	4	M 1, M 8, M 45, M 52	59 / 68	86.8	33 / 40	82.5	92 / 108	85.2
DFA 6	5	M 1, M 5, M 8, M 12, M 17	63 / 74	85.1	36 / 41	87.8	99 / 115	86.1
DFA 7	3	M 1, M 8, M 17	67 / 82	81.7	39 / 50	78.0	106 / 132	80.3
DFA 8	4	M 1, M 8, M 45, M 48	58 / 67	86.6	34 / 41	82.9	92 / 108	85.2
DFA 9 (a)	5	M 5, M 17, M 45, M 47, 51 (b)	54 / 64	84.4	33 / 40	82.5	87 / 104	83.7

(a) stepwise DFA of 12 variables
(b) variables entered
(c) M1, M 8, M 9, M 12, M 40, M48, M 52 - variables that did not enter
N = ratio of sexes correctly identified to the total of thet sex examined in a given DFA
M = symbol of measurements after Martin (Bräuer 1988)

sex determination of skull from 28 individuals determined by primary sex diagnosis.

Secondary sex diagnosis (SSD) was carried out on specimens from both Mikulčice burial sites, that is, on individuals whose sex had been determined by PSD and from which we could take cranial measurements. We thus had 98 skulls belonging to males and 61 skulls belonging to females for the proposal of discriminant functions. This number is somewhat lower than the number of individuals whose sex was determined using the pelvis, as the skulls of a certain number of individuals had not preserved.

The basis for the calculation of discriminant functions is 12 cranial measurements,

Table 7. Discriminant function analyses of cranial variables in Great Moravia burial- ground samples with classification rules for correct identifying of sex with probability of 50% (correct discrimination). Key to measurements in the Table 2.

Discriminant Function (DF) N°	Equation	Classification p = 0,5	Centroid
DFA 1	(M 1 * -0,159) + (M 40 * -0,044) + (M 45 * -0,180) + (M 48 * -0,037) + 59,478	F > 0 > M	2.983
DFA 2	(M 1 * -0,098) + (M 5 * -0,196) + (M 8 * -0,005) + (M 45 * -0,164) + (M 48 * -0,034)+ 62,209	F > 0 > M	3.417
DFA 3	(M 1 * -0,088) + (M 5 * -0,206) + (M 8 * -0,023) + (M 45 * -0,158) + 60,607	F > 0 > M	3.256
DFA 4	(M 1 * -0,123) + (M 17 * -0,183) + (M 45 * -0,151) + 66,829	F > 0 > M	3.331
DFA 5	(M 1 * -0,183) + (M 8 * +0,001) + (M 45 * -0,183) + (M 52 * -0,046) + 58,784	F > 0 > M	2.270
DFA 6	(M 1 * -0,124) + (M 5 * -0,163) + (M 8 * -0,093) + (M 12 * +0,111) + (M 17 * -0,228)+ 70,583	F > 0 > M	3.877
DFA 7	(M 1 * -0,143) + (M 8 * -0,053) + (M 17 * -0,184)+ 58,446	F > 0 > M	2.555
DFA 8	(M 1 * -0,186) + (M 8 * +0,013) + (M 45 * -0,191) + (M 48 * -0,039) + 60,001	F > 0 > M	3.052
DFA 9	(M 17 * -0,126) + (M 47 * -0,106) + (M 5 * -0,197) + (M 45 * -0,109) + (M 51 * -0,053)+ 65,354	F > 0 > M	4.033

whose basic statistics are given in Table 4. There were significant sex differences in all of the measurements studied in the skulls from Mikulčice (Table 4). The average value of measurements is significantly higher for males than for females.

We calculated nine discriminant function analyses (DFA), which are summarised in Table 5. Eight DFA are classic linear discriminant function analyses, the ninth is a forward stepwise discriminant function analysis. The selection of measurements was based on measurements commonly used to determine sex on the basis of the skull. The number was optimised to take the condition of the skeletal material into account. The first DFA includes four measurements, of which two describe the neurocranium and two the face. The second DFA combines three measurements of the neurocranium with two measurements of the face. The third DFA is a modification of the second DFA with three measurements of the neurocranium and the width of the face, while the fourth DFA only uses three cranial measurements. The fifth DFA uses four measurements, two of the neurocranium and two of the face. The sixth and seventh DFA only uses neurocranial measurements. The eighth DFA once again combines measurements of the face and neurocranium. The final, stepwise DFA chose five of the total 12 measurements which contributed to the separation of males from females. According to Wilks' lambda statistics values, all DFA are significant. Wilks' statistics have a value from 0 (absolute discrimination between groups) to 1 (no discrimination between groups).

Table 6 shows the sexing accuracy for 9 DFA in the sample of early medieval Slavonic crania. All of the proposed DFA have a sexing accuracy higher than 80%, of which DFA 6 has the highest rate with 86%. However, the risk of error is relatively high and, depending on the each or particular DFA, ranges from 14 to 20%. The calculation of DFA was only possible for approximately two thirds of the starting number of 98 males and 61 females whose sex was determined according to the pelvis, as individuals with incomplete data were removed from the calculation.

Table 8. Test of the discriminant function analyses of cranial variables in population sample from Prušánky burial-ground (classification rule: p = 0,5). DFA 1, DFA 2, DFA 3 ……= values of discriminant function analysis; 1, 2, 3…..PSD = primary sex diagnosis, SSD = secondary sex diagnosis; M= male, F = female, ?= indetermined sex; * false sex

N° grave	"PSD"	DFA 1	sex	DFA 2	sex	DFA 3	sex	DFA 4	sex	DFA 5	sex	DFA 6	sex	DFA 7	sex	DFA 8	sex	DFA 9	sex	Applica-bility	"SSD"
10	F	-	?	-	?	-	?	-	?	-	?	-	?	-	?	-	?	-	?	0/9	?
26	F	2.147	F	2.164	F	1.835	F	0.838	F	1.719	F	0.107	F	0.841	F	2.151	F	2.756	F	9/9	9F
58	F	-	?	1.818	F	1.671	F	2.974	F	1.904	F	4.61	F	2.902	F	2.09	F	2.779	F	8/9	8F
61	F	-	?	-	?	-	?	-	?	-	?	-	?	-	?	-	?	-	?	0/9	?
62	F	1.903	F	2.044	F	1.703	F	1.662	F	1.449	F	2.03	F	1.59	F	1.787	F	2.858	F	9/9	9F
67	F	1.104	F	0.84	F	0.515	F	0.455	F	0.574	F	1.097	M *	0.258	M *	0.921	F	1.982	F	9/9	7F
174	F	-	?	-	?	-	?	-	?	-	?	-	?	-	?	-	?	-	?	0/9	?
182	F	-	?	-	?	-	?	-	?	-	?	-	?	-	?	-	?	-	?	0/9	?
212	F	2.316	F	2.155	F	1.63	F	2.513	F	1.814	F	2.37	F	2.195	F	2.351	F	3.908	F	9/9	9F
214	F	-	?	0.98	F	0.801	F	2.244	F	0.49	F	3.362	F	2.486	F	0.673	F	2.739	F	8/9	8F
251	F	0.699	F	1.269	F	0.864	F	0.738	F	0.371	M *	0.726	F	0.096	M *	0.217	F	4.665	F	9/9	7F
252	F	-	?	-	?	-	?	-	?	2.743	M *	-	?	-	?	2.408	M *	-	?	2/9	2M
283	F	-	?	-	?	-	?	-	?	-	?	-	?	-	?	-	?	-	?	0/9	?
18	M	1.13	M	1.401	M	1.28	M	1.935	M	0.977	M	2.277	M	1.198	M	1.142	M	2.502	M	9/9	9M
22	M	1.088	M	0.25	M	0.397	M	1.488	M	1.513	M	1.341	M	2.009	M	1.36	M	0.065	M	9/9	9M
34	M	4.901	M	4.085	M	4.146	M	5.629	M	4.806	M	4.953	M	4.862	M	4.784	M	3.456	M	9/9	9M
50	M	0.293	M	0.387	M	0.288	M	0.715	M	0.016	M	0.229	M	0.217	M	0.202	M	1.247	M	9/9	9M
64	M	-	?	-	?	-	?	-	?	-	?	-	?	-	?	-	?	-	?	0/9	?
65	M	-	?	-	?	-	?	-	?	-	?	-	?	-	?	-	?	-	?	0/9	?
75	M	1.648	M	2.132	M	2.113	M	1.512	M	1.66	M	2.127	M	1.009	M	1.769	M	2.001	M	9/9	9M
84	M	-	?	-	?	-	?	-	?	0.354	F *	-	?	-	?	0.446	F *	-	?	2/9	2F
129	M	0.532	M	0.727	M	0.922	M	1.506	M	0.555	M	1.961	M	1.258	M	0.484	M	1.505	M	9/9	9M
138	M	3.278	M	3.798	M	3.489	M	1.912	M	2.944	M	2.202	M	1.25	M	3.189	M	3.706	M	9/9	9M
154	M	-	?	-	?	-	?	-	?	-	?	-	?	-	?	-	?	-	?	0/9	?
178	M	1.093	M	1.199	M	1.21	M	0.809	M	1.069	M	0.811	M	0.237	M	0.981	M	0.259	M	9/9	9M
189	M	-	?	-	?	-	?	-	?	0.083	F *	-	?	-	?	0.362	F *	-	?	2/9	2F
210	M	3.084	M	3.971	M	4.318	M	2.907	M	2.88	M	3.866	M	2.315	M	2.789	M	2.688	M	9/9	9M
266	M	0.574	M	0.594	M	0.671	M	0.503	F *	0.373	M	0.267	M	0.492	F *	0.418	M	0.185	F *	9/9	7M
correct			*15/28*		*17/28*		*17/28*		*16/28*		*16/28*		*16/28*		*14/28*		*17/28*		*16/28*		
indetermined			*13/28*		*11/28*		*11/28*		*11/28*		*8/28*		*11/28*		*11/28*		*8/28*		*11/28*		
error			*0/28*		*0/28*		*0/28*		*1/28*		*4/28*		*1/28*		*3/28*		*3/28*		*1/28*		

The Statistica 7.01 software we used gives two linear equations as the result of DFA for two groups, into which the appropriate values for cranial measurements taken are placed for the case we wish to classify. A higher result for one of the two equations determines the group to which the new case belongs. In order to simplify application, we subtracted two classification functions from each other to obtain at a single, standardised equation. The final DFA are summarised in Table 7. Cranial length (M1 – Maximum Cranial Length) and bizygomatic facial width (M45 - Bizygomatic Width) are of the greatest significance for determining sex, as the coefficient values of these measurements are highest for individual DFA. However the proposed DFA can only be used for old Slavonic (Great Moravian) populations of the early medieval period in Central Europe. We compare the result of the linear equation (DFA) for the unknown case with the male-female sectioning point, which in the case of a standardised equation equals 0, as the value of the centroid for men and women is the same. A positive value indicate a female sex and a negative value, a male sex. Values in the interval near zero must be considered as indeterminate cases, independently from the assigned sex by the discriminant function.

To verify the accuracy of the proposed DFA, we carried out a reliability test on a small sample of 28 skulls (13 females and 15 males) from the Prušánky I burial site, whose sex was determined in advance by PSD. The Prušánky I burial site is located in the hinterland of the Mikulčice centre and also dates to the Great Moravian period. The results of the test are presented in Table 8. We were able to determine the sex of 15 to 20 individuals using the proposed DFA. It was not possible to apply some of the DFA in eight to thirteen cases, while it was not possible to apply any of the 9 DFA for seven skulls. Sex determined on the basis of the first three DFA always corresponded to primary sex diagnosis based on the pelvis. Of the remaining 6 DFA, an error compared to primary sex diagnosis range from three cases of the 17 skulls to four cases of the total number of 20 skulls determined by DFA. This is an error rate from 18 to 25%, which corresponds to classification accuracy (Table 6). Based on this test, it can be said that the proposed DFA are reliable and can be used for the purpose (determining sex of skulls in early Slavonic population) (for which they were presumed).

4. Discussion

The population specificity of DFA reflects the fact that skeletal sexual dimorphism is influenced by the greater body size, larger joints and stronger musculature of males compared to females in a considered population. The existence of a secular trend, not only causes variations in body size and stature (body height) between generations (Meadows/Janz 1995; Klepinger 2001), but also has an impact on changes in the measurements of several bones (e.g. Jantz 1999; Bidmos 2006). The DFA calculated in the collection of skeletal remains of known age and sex from individuals living tens or even hundreds of years ago, cannot reflect changes in the sexual dimorphism of body size the past populations living in the same region for example 1500 years ago. For this reason the DFA cannot be a general and reliable tool for sex determination. This is also evidenced by the wrong use of specific discriminant functions derived from measurements of the long limb bones in the recent American population by Işcan/Miller-Shaivitz (1984) and applied to the Neolithic Danish population sample by Götherström et al. (1997). The results of sexing were compared with results of sex determination based on ancient DNA and the discordance of both approaches led to an erroneous rejection of morphometric methods as a whole and unjustified confidence in molecular-genetic methods (Götherström et al. 1997).

The population-specificity of discriminant functions has also been accentuated in many recent publications (e.g. Bidmos/Dayal 2004;

WALRATH/TURNER/BRUZEK 2004), yet despite this we are witness to a continuing explosion of proposed morphometric methods which recognise this fact, yet do not respect it (e.g. ASALA 2001; BIDMOS/ASALA 2004; BURROWS/ZANELLA/BROWN 2003; KEMKES-GROTTENTHALER 2005, PURKAIT/CHANDRA 2004; ŠLAUS et al. 2003; FRUTOS 2005; DAYAL/BIDMOS 2005). Although these are studies utilise the bone samples from one population, some authors assume or even recommend the general use of these tools without any form of restriction.

In this contribution we have also tried to use the population specificity of cranial measurements to determine sex. The use of the skull for secondary sex diagnosis is just one of the steps that need to be taken to sexing skeletons from the burial sites. Other parts of the skeleton can also be used for this purpose. For this reason we have not analysed the percentage of skeletons from the entire burial site whose sex was determined using DFA skull measurements. This percentage depends on a wider array of factors. We have simply emphasised the demonstrable possibility of reliable sexing of a skull using DFA even in those cases where skeletons of known sex are not available.

However, we must emphasise the difference between statistical accuracy of the discrimination (or classification) based on general statistical decisions theory and reliable accuracy of the discrimination (or classification) required by the empirical strategy of anthropological practice. For each application of discriminant function, sex assessment of a new case depends on the computation of a discriminant score (DS) which is compared to the discriminant value (DV) separating males from females. In the overlapping area of DFA values for males and females, it is not possible to decide whether an unknown case for which we wish to determine sex is a true female or a false female, respectively, an incorrectly diagnosed male, as both have the same discriminant score value. In principle, the above two approaches differ in the severity of classification rule applied. In the

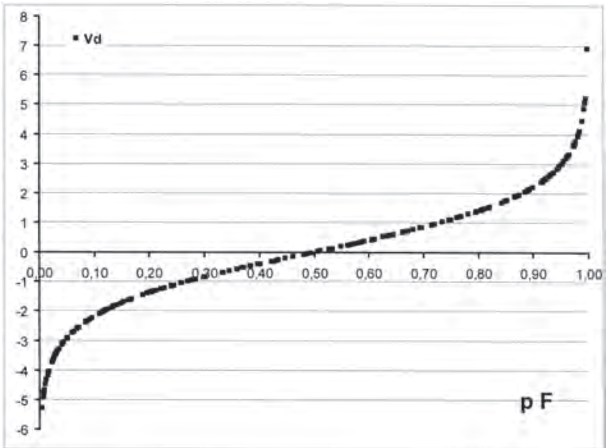

Fig. 2. Example of relationship between probability of sex allocation (axis x) and the posterior probability or discrimination score of DFA 2 (axis y) for female skulls from Mikulčice.

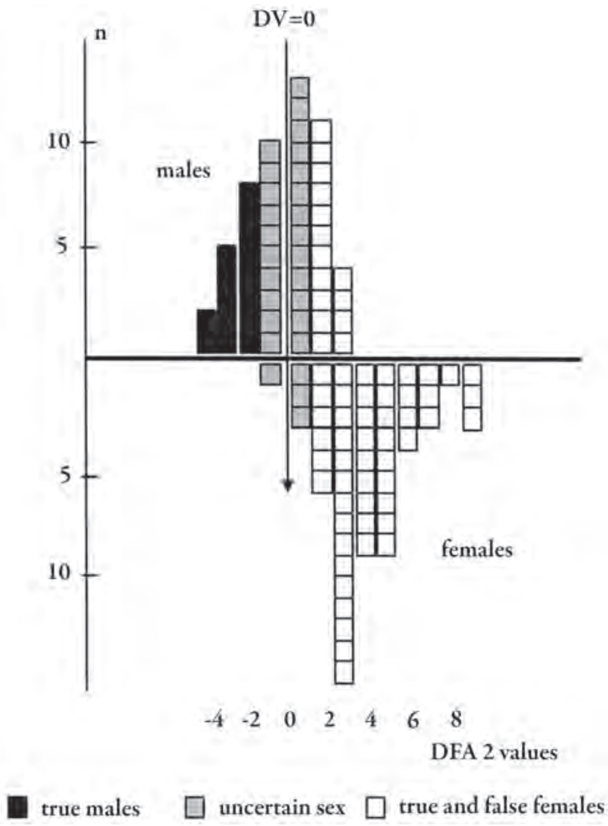

Fig. 3. The shift of distribution accuracy in correctly determining sex for a group of skulls from Coimbra collection of identified skeletons using a DFA 2 from the "Great Moravian" population.

first of these cases, we use for separation of two groups a posterior probability value equal to 0.50 (the sectioning point), where the degree of certitude of correctly classifying an individual is lower in proximity of of the sectioning point. The accuracy is growing that nearer the individual value of Mahalanobis's distance approaches the centroid for the given sex. In the second case of reliable accuracy of the classification, we use a posterior probability value equal to 0.95, which is must severe and resemble to a certitude that the given individual really belongs to the given sex. In practice however, if we cannot apply such severe criteria (small number of individuals, poor preservation of material) we must choose a somewhat lower posterior probability level than 0.95, but which must not fall below 0.70. According to Hanihara (1981) such a probability value gives a high degree of guarantee of correct sex diagnosis. The risk of misclassification or erroneous diagnosis rises near to the sectioning (dividing) point.

What sex should be allocated to a skull that could belong to a male with 0.55 probability, if we know that, in such a case, the probability that it is a female skull is 0.45? For the proposed DFA for skulls from old Slavonic populations of the early medieval period, we recommend using the indeterminate sex interval in which the posterior probability for male and female diagnosis is very close. This approach is illustrated by DFA 2 and the graph showing the relationship between posterior probability and the distribution of the discriminant scores (Figure 2).

It is evident from the graph that the sex allocation is uncertain in interval of the discrimination score values from –1 to +1. In this interval the sex must be considered as indeterminate. In order to confirm the population specificity of the proposed discriminant functions, we have presented the results of a simple test. Once again we chose DFA 2 and using this function tried to determine the sex of recent adult skulls of known sex and age originating from Portuguese Coimbra. This involved the skulls of 107 individuals (53 males and 54 females) which were measured by one of the authors (Bruzek et al. 2004) and which were used previously for testing the ForDisc 2.0 program (Ousley/Jantz 1996). As shown in Graph (Figure 3), the sex of only 28% of male skulls (15 of 53) was reliably determined using "Great Moravian" DFA 2. This was significantly better for the females in the group, where DFA 2 confirmed the sex of almost 93% of female skulls (50 of 54). It is also evident from Graph (Figure 3) that 23 males and 4 females out of the 107 individuals tested fell in the interval of "uncertain or indeterminate values", i.e. the overlap zone, with discriminant scores of -1 to +1. These results confirmed the population specificity of Great Moravian DFA 2. Sexual dimorphism exists in both groups, that is, both the Great Moravian and recent Portuguese group; however the size factor shifts the discriminant value of DFA 2 towards male individuals, which means the Portuguese skulls are finer.

For comparison, we calculated a discriminant function for the set of skulls from Coimbra based on identical measurements as those used for the "Great Moravian" DFA 2 and the resulting classification correctly identified 88% of individuals. The test confirms the population specificity of DFA cranial measurements and the suitability of secondary diagnosis in every population.

The proposed discriminant functions for the determination of sex based on the skull for early Slavonic medieval populations have a same accuracy indicated for the skull by various authors. This accuracy ranges from 77% to 85% (Boulinier 1968; Giles/Elliot 1963; Meindl et al 1985; Steyn/Işcan 1998; Franklin/Freedman/Milne 2005 and others). The accuracy of the discrimination is not however the only criteria affecting the discriminatory power of DFA. Except for biological factors, it is also affected by the size of the sample and number of measurements employed (Van Vark/Schaafsma 1992).

When determining sex and evaluating the accuracy of the used methods, archaeological and cultural aspects must also be taken into consideration. There is a consensus in biological anthropology in which sex is a biological category determined at the moment of conception which is a process of sex differentiation and development, also of a biological nature, that allows us to distinguish between male and female individuals. On the other hand, gender is a category or a cultural and social construction according to which individuals are classified or considered as men or women. An individual gender identity and social position are also dependent on the psychological factors and «brain gender». In many human societies, the position of the man (male gender) is more advantageous as it is associated with better living conditions. There are also societies that recognise more than two sexes and individuals can go from one category to another during their life. Although rare, such cases do exist and in the archaeological context may explain the inability to obtain absolute agreement between sex and gender. According to GAUTHIER (2000), an autopsy of Vittoria Colonna's mummy, the wife of Ferdinando d'Avalos, who lived in the 16th century in Italy, revealed that it was in reality a man. For this reason it is important to clearly distinguish between sexes as a biological category according to which we classify human remains and the gender as a psycho-social category of the person during his/her lifetime (TAYLOR 1998). It is thus impossible to expect absolute sex determination of male and female individuals on the basis of somatic sex criteria. Therefore it is generally allowed that the 95% threshold represent the maximum success of sex diagnosis on the basis of the skeleton.

Classic multivariable statistical tools such as discriminant function analysis, do not allow the overly successful differentiation of two population groups of skulls due to extensive intra population variability, which is greater than the actual differences between the groups (BRUNER/RICCI/MANZI 2002). New methods such as geometric morphometry have an advantage over multivariable statistics in that they can localise the area of the cranium whose morphometric characteristics most contributed to the differentiation of the group of skulls (ROSS/MCKEOWN/KONIGSBERG 1999). Significant biological differences in cranial shape, ascertained using geometric morphometry, allowed the authors, for example, to explain the population affinity of the Cuban population of the 19th century and contribute to identification criteria for the South Florida population of Cuban Americans (ROSS et al. 2004). Although this primarily relates to the American population and estimated population affinity, it can be assumed that geometric morphometry can also be used in anthropology studying sexual dimorphism and its applications, which includes the sex determination of individuals from past human populations.

5. Conclusion

The proposed discriminant functions are suitable for determining the sex of early medieval skeletons from the Great Moravian region only (without the influences of nomadic asian peoples). They are designed for a quick, preliminary determination of sex of skull in the field work and are a available technique in the absence of the pelvic bone. The accuracy of sex determination is around 80%.

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Genetic Sex Determination of Sub-adult Individuals from the Great Moravian Settlement in Mikulčice (9th Century AD)

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Specimens of human sub-adult bones from the Mikulčice settlement (9th century) were genetically investigated for sex determination, the main goal of this study. DNA sequence length differences in the amelogenin gene locus were chosen for their importance in sexing. A PCR system that focuses on the Y chromosome was applied to confirm the amelogenin sexing results of female individuals. We have shown that a second system for sex determination is essential, because allelic drop-out is very frequent among samples of aDNA amplicons. The reliability of the genetic analysis was verified on a set of 5 adult individuals with morphologically determined sex. The genetic analysis was successful in 37 out of 47 sub-adult individuals (78.7%). The data obtained showed a higher presence of male individuals – 24 males to 13 females. The number of sub-adult individuals studied was too low to statistically confirm the significance of the higher number of male individuals. As a second step in our research, we took information from genetic analysis as a standard, and applied specific morphological methods to estimate its validity. We checked sex by means of two qualitative methods based on the morphological traits of the hip bone and mandible. We determined the sex of 23 out of 37 genetically determined skeletons (62.2%). Likewise, the genetic analysis results showed a uniquely higher presence of male sub-adult skeletons – 19 males to 4 females. The concordance between the genetic and morphological sex determination was remarkably high at 87%. In view of the low sexual morphological dimorphism of immature skeletons, we consider the 87% value of concordance to be a speculative result. Nevertheless, selected morphological methods have proved to be very useful when applied to individuals from the 9th and 10th centuries. Records of grave goods were also included in the final sex evaluation, and this multidisciplinary approach has yielded interesting results. The higher male to female ratio will be further studied.

Key words: Early Medieval population – sub-adult individuals – genetic sex determination – morphologic sex determination

1. Introduction

The Mikulčice settlement is located in south Moravia in a low-lying region where the highest point does not even reach 300 m above sea level. The climatic, pedologic and other natural conditions in this area made it suitable for the development of agriculture. Cremation was the main method used for disposing of the dead between the 6th and 8th centuries. From the turn of the 8th and 9th centuries, inhumation predominated and thus anthropological studies focus on this period of time. From the demographic point of view, burials of immature individuals usually represent more then 40% of all burials (e.g. Stloukal 1989). Current osteological methods allow the relatively precise determination of age at death of sub-adult skeletons, but sex determination is very problematic.

The main aims of our study were to determine the sex of a group of sub-adult individuals

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from the Mikulčice settlement cemetery using genetic methods, and to establish a reliable protocol for aDNA analysis. The sex information in this group of sub-adult individuals would serve as a standard for the development of new morphological methods. Selected morphological methods would be applied to the same group of individuals to validate them. There are several grave goods records from Mikulčice cemetery which would be used for the final sex determination.

1.1 aDNA

This study applied genetics to archaeological finds. Ancient DNA (aDNA), first introduced by Higuchi (Higuchi et al. 1984), has great potential in archaeology. The extraction and analysis of this highly informative molecule provides insights into many fields of research. Anthropologists mainly focus on aDNA research that may answer questions regarding population characteristics. On the level of a human individual, aDNA genetics are able to determine sex, hereditary and infectious disease that may have caused death, and even a relationship between the individual studied and other people.

1.1.1 aDNA molecule status

The nature of aDNA differs from recent DNA molecules. After a long time spent in a burial environment, aDNA is present in very low quantities and fragmented into short sequences. The aDNA bases have been chemically modified to a great extent (Hoss et al. 1996; Lindahl 1993). Those properties have a noticeable effect on the amplifiability of ancient DNA through the use of PCR methods. For aDNA analysis, the aim is to amplify fragments to lengths of around 150bp, because aDNA has been degraded and fragmented into pieces usually shorter than 200bp (Paabo 1989).

Contamination with exogenous DNA and very low amounts of endogenous aDNA are the biggest challenge faced (Handt et al. 1996; Montiel/Malgosa/Francalacci 2001). Strict precautions must be taken to ensure that authentic aDNA is obtained. There are overwhelming numbers of sources of potentially contaminating molecules and, unfortunately, modern DNA copes with genetic analysis more easily than ancient molecules. Cooper and his colleague have published a set of rules to eliminate contamination in aDNA studies (Cooper/Poinar 2000).

1.1.2 Scope of aDNA applications

Regarding the question of sex, two out of 46 chromosomes determine whether a person will be male or female. With exceptions, females are carriers of two X chromosomes, while males carry one X and one Y chromosome. The region shared by both sex chromosomes is very short. In this pseudo-autosomal region there is, among other things, a gene for the protein amelogenin that has minor differences in its DNA sequence between the two sexes. The detection of these differences is the main goal of genetic sexing analysis. Since the DNA fragment for sex determination is present even in ancient biological material, its analysis is becoming established in archaeogenetic laboratories worldwide.

To answer the question about specific hereditary disease one must detect causative aDNA mutation in an appropriate gene. Using aDNA analysis, the delta F508 mutation that causes cystic fibrosis has been successfully detected in a historical specimen (Bramanti et al. 2003).

Several infections affecting the quality of human life were common in the medieval period. Infectious diseases are caused by pathogenic agents such as bacteria, viruses or protozoa. Detection of their DNA indirectly confirms their presence in an ancient human body. Recent history has seen several cases of successful pathogen detection in archaeological specimens. *Yersinia pestis*, for example, was successfully detected in dental pulps of individuals from France, from specimens 400 years old (Drancourt et al. 1998). Among others, we should mention the detection of *Plasmodium falciparum* (Taylor/Rutland/Molleson 1997) and *Mycobacterium leprae* (Rafi et al. 1994) – pathogens causing malaria and leprosy respectively. A study conducted in the

Czech lands proved the presence of leprosy in the bones of human individuals who died before the Crusades, the main source of widespread leprosy in Europe (Likovsky et al. 2006). Even though the syphilis agent has been genetically determined in mummies from Easter Island (Kolman et al. 1999), recent research into syphilis suggests that its DNA cannot be detected due to its rapid and total degradation in an open environment (Bouwman/Brown 2005).

Confirming kinship between individuals excavated in close proximity (suggesting a close relationship) is a big challenge for anthropologists today. The genetic approach to relationship detection works well for forensic laboratories but is not, unfortunately, that successful in aDNA studies. Every individual is a genetic mix of their parents, with each parent giving exactly one half of their genes hidden in the cell nucleus to their offspring. Close examination of the DNA pattern can precisely detect such direct relationships. Genetic approaches focus on analysis of STR loci (short tandem repeat) polymorphism in autosomes, Y chromosomes and on mtDNA (mitochondrial DNA) hyper-variable region examination.

Until today not many results have been publicly known concerning the STR analysis of ancient related individuals. A group of biomolecular archaeologists from Germany has gone furthest in this task, for example (Gerstenberger/Hummel/Herrmann 2002). Their studies show the possibility of information retrieval with many methodological restrictions – underestimation of larger STR alleles, high allelic drop-out frequency, etc. According to their studies, it is possible to use recent data from population genetics and to apply these on a population from ancient times without loss of information.

The mtDNA molecule is strictly transmitted from mother to offspring and there are thousands of copies of mtDNA in a cell, compared to only two copies of nuclear DNA in chromosomes. The biggest problem in mtDNA analysis is the ease of contamination by recent mtDNA and the high mutation rate. The Y chromosome, on the other hand, is transmitted strictly from males to male offspring. Its STRs are analyzed when seeking to detect relationships between male individuals as close male relatives should have the same STR profile.

At the level of groups of human individuals, kinship genetics analysis may be employed together with population origin, migration patterns, the spectrum of infectious diseases, the degree of endo/exogamy, as well as the social behaviour of earlier human societies.

1.2 Genetic approach to sex determination

Molecular genetic analysis of aDNA allows determination in skeletons of sub-adult individuals in cases where morphological methods are restricted due to a lower manifestation of sexual dimorphic indicators. Not only sub-adult bones but also fragmentary osteological material is highly suitable for such an approach.

Many anthropological investigations employ genetic methods to uncover information about sex that can uncover new social and cultural facts about our ancestors (e.g. Faerman et al. 1998; Faerman et al. 1995; Gotherstrom et al. 1997; Stone et al. 1996). In a study by Mays (Mays/Faerman 2001), it was speculated that infanticide occurred during the Roman Britain period because many skeletons were found to be neonates (38-40 weeks of gestational age) when age at death distribution was monitored. aDNA analysis confirmed the sex of 13 neonates (nine males and four females). This result cannot directly prove infanticide in favour of one sex due to the low number of successful aDNA analyses, but it gives rise to many anthropological questions.

1.3 Morphological approach to sex determination

Skeletal morphological differences between the sexes exist from the intra-uterine stage onwards, but they probably do not reach a sufficiently high level for the reliable determination of sex until after the pubertal modifications take place (Scheuer/Black 2000). The mineralization of dentition shows less sexual dimorphism than do the rates of skeletal maturation (Scheuer/Black 2000).

Many morphological methods for sex determination of immature skeletons currently exist. Due to the low expressivity of sexual dimorphism, most of these methods usually report a 60-90% success rate in sexing (e.g. Mittler/Sheridan 1992; Weaver 1980). In addition, the validity and reliability of many of these methods have not been tested. One of the reasons for this is the lack of samples of known biological identity. The essential problem is the different age structure of skeletal samples for which such methods have been proposed.

Most frequently, the following morphological characteristics are utilized for sex diagnosis: general shape of the pelvis, in particular, the greater sciatic notch and the sub-pubic angle (Schutkowski 1993), configuration of the auricular surface of the sacro-iliac joint (Mittler/Sheridan 1992); the morphology of the mandible (Loth/Henneberg 2001); differences in the robusticity index of the humerus and femur (children aged between 0 and 4; (Coussens et al. 2002); the dimensions of teeth (deVito/Saunders 1990) or the shape of the orbit (Molleson/Cruse/Mays 1998).

With regard to the lack of sex dimorphism in the sub-adult skeleton, we cannot utilize the term "sex determination" in sex morphological methods, but rather "sex estimation" (e.g. Lewis 2007; Saunders 2000; Scheuer/Black 2000). In comparison, sex determination in skeletons of adult individuals – skeletons with finished "ontogenesis" and a "definitive" magnitude of sex dimorphism – generally has a success rate of over 95% when based on morphology of the pelvic bones. With regard to the fact that the sex dimorphism of all human bones, with the exception of the pelvis, is population specific, it is appropriate to apply the technique of primary and secondary sex diagnosis (Murail et al. 2005).

2. Materials and methods

2.1 Contamination precautions

Precautions were taken against contamination with intrusive DNA (Poinar 2003). aDNA extraction procedures were conducted in a room where no modern DNA had ever been isolated. This room was separate from the laboratory where PCR and electrophoresis took place. All the laboratory equipment was maintained in such a way as to keep it uncontaminated. We used 5% hypochlorite and household bleach for instruments and surfaces. Plastic gloves were changed frequently. Plastic laboratory ware and glass vessels were autoclaved before use. The isolation of aDNA and PCR mastermix was set up in a laminar flow cabinet and a system of "blind" controls was applied.

2.2 Sample collection

We have selected a group of 47 sub-adult skeletons excavated in the Mikulčice settlement between 1957 and 1988. These human individuals were chosen for the high degree of preservation of specific bones – a high state of preservation of the maxilla, mandible, teeth, pelvic bones and long bones of the upper and lower limbs. The whole group of 47 sub-adults consists of individuals whose age span is from 18 months to 17 years. This collection will serve in the future for other scientific purposes – mainly for the development of new morphological methods for sex determination in sub-adults.

We have taken five adult individuals from the same cemetery. These skeletons have a high expression of morphological traits for sex determination. These individuals will be genetically analyzed for sex using laboratory procedures. The data obtained will be compared with sex-related data determined using morphological methods. Morphological determination of sex of those selected individuals will have high credibility. If molecular biology provides similar results, one can objectively consider such a study to be reliable. We presume that a high degree of data agreement between the two different approaches (95% and more) will confirm the reliability of both methods. High concordance should strongly support the authenticity of the aDNA studied using our laboratory procedure. The morphological sex was unknown to the geneticist.

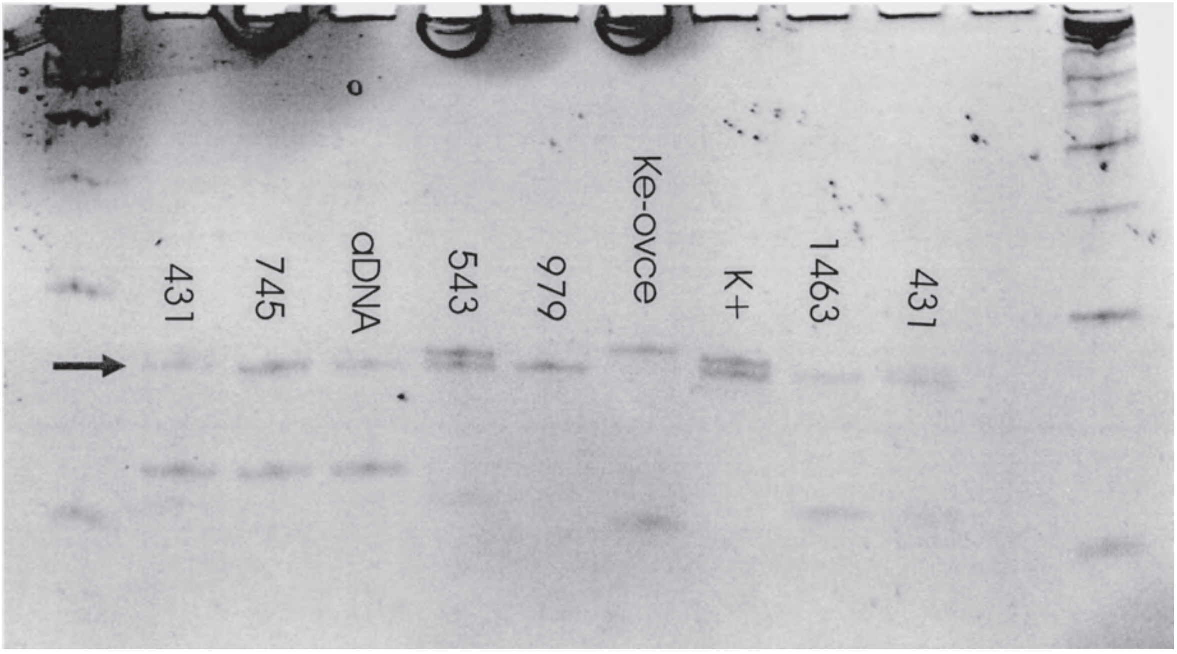

Figure 1. PAGE gel. Number on the figure represents grave number of the specific subadult individual. Positive control – K+ is used for monitoring the success of amplification, its DNA belongs to a man from recent population. aDNA notation represents a historic sample that is not part of this study. Ke-ovce notation represents isolation control – aDNA sample of sheep (amelogenin PCR fragment of different length). The arrow identifies the area for reading the proper length of a PCR fragment Amel 80/83. Double band represents lengths of 80/83bp (male) and single band 80/80bp (female).On the first and the last row of the PAGE gel there is a length marker. Allelic drop-out is apparent for the first sample of individual 431.

2.3 Genetic approach

2.3.1 Extraction of ancient DNA

For genetic analysis two teeth per individual were withdrawn. All such handling took place so that the samples were protected from contamination. Whenever possible, only uncarved teeth were withdrawn. The selected teeth from both groups (sub-adult and adult) had no cavities or visible holes and no openings into the pulp were apparent, according to Richards/Sykes/Hedges 1995. The intact teeth were soaked in 5% hypochlorite to decontaminate the surface. 5 min of UV light exposure (254nm) was applied on all sides. The specimens were ground to a fine powder using a vibrating mill.

For extraction, we used a modification of the original Evison protocol (Evison et al. 1997), with only minor changes applied for our laboratory purposes (Bromová et al. 2003). About 0.5g of bone powder was mixed with 0.5M EDTA (pH 8.0) for two days in a rotary mixer. Proteinase K was then added and the contents were kept in motion for one more day. The extraction procedure then consisted of steps including the addition of 4M GuSCN (pH 7.0) and 20μl silica solution and incubation for two hours in a rotary mixer. The pellet formed by the aDNA and silica suspension was, after a short spin, washed twice in 70% ethanol and once in acetone. The aDNA was eluted in water and stored in a freezer at -20°C. One to three rounds of extraction from the same bone sample were used to investigate whether or not this could influence the aDNA yield.

2.3.2 Amplification of nuclear aDNA

The PCR reaction was performed in the Techne cycler (Techgene) in a total volume of 25μl. 7μl of aDNA extract was added to the reaction consisting of 7pmol of primers Amel 80/83 (Haas-Rochholz/Weiler 1997) and Fermentas chemicals: 1x buffer, 0.2mM dNTPs,

Table 1. The confrontation of results of morphological and molecular genetic sex determination of the five adult individuals from Mikulčice.

		Primary sex diagnosis			Secondary sex diagnosis [41]		Genetical analysis
Sample No.	Grave No.	pF	pM	Visual	SD1 F	SD1 M	Teeth
1	1588	0.999	0.001	F	0.997	0.003	F
2	1648	0.936	0.064	F	0.705	0.295	F
3	1784	0.001	0.999	M	0.373	0.627	M
4	1821	0.007	0.993	M	-	.	M
5	1835	0.971	0.029	F	0.874	0.126	F

name – inventory number of the skeleton
pF – probability of female sex by primary diagnosis (metric approach)
pM – probability of male sex by primary diagnosis (metric approach)
visual – result of visual approach of primary diagnosis
SD1 F – female posterior probability of discriminant function based on the cranial measurements
SD1 M – male posterior probability of discriminant function based on the cranial measurements
F – female, M – male individual

2.25mM MgCl2, 40ug BSA and 0.625U Taq polymerase. Another amplification system for sex determination was applied – DYZ1 – Y repetitive segment 102bp long (Pfitzinger/Ludes/Mangin 1993). This system securely identifies male individuals in cases where there is a female appearance at the amelogenin locus caused by allelic drop-out of the Y-amelogenin locus. The amplification reaction was also performed in 25µl of $MgCl_2$ at a concentration of 3.0mM. Both systems were employed several times to rule out the possibility of allelic drop-out and unsuccessful amplifications.

2.3.3 Analysis of amplified products

A volume of 8µl of amplified product was analyzed for its length first on 2% agarose gel electrophoresis. If a product was detected with ethidium bromide staining, then the particular sample was placed on 14% polyacrylamide gel electrophoresis (PAGE) for detection of potential 3bp length-difference in male individuals (see figure 1). The PCR product of DYZ1 was analyzed only on 2% agarose gel.

2.4 Morphological approach

The sexing of immature skeletal remains was determined on the basis of two morphoscopic evaluations of certain morphological characteristics of the pelvic bone and mandible. The first method, proposed by Schutkowski (Schutkowski 1990, 1993), evaluates both mandibular and pelvic traits: protrusion of the chin region, the shape of the anterior dental arcade and eversion of the gonion region on the mandible, the angle and depth of the greater sciatic notch, and "arch" criterion and curvature of the iliac crest on the iliac bone. This method was derived from an ancient sample of immature skeletons of known sex and age from Spitalfields.

The second method applied was taken from Molleson and her colleagues (Molleson/Cruse/Mays 1998). Determination of sex is based on the character of the mandibular angle, mentum and the shape of the orbit. The shape of the orbit was not evaluated in this study. The method was proposed on non-adult (juvenile) skeletons of known sex and age from Christ Church Spitalfields.

In total, we evaluated seven qualitative traits – the iliac bone and the mandible separately. For the mandible we recorded four visual scopic characteristics applying the aforementioned methods. Final sex determination was carried out as a summary of all the evaluated morphoscopic traits.

Table 2. Sex of subadults – the comparison of genetical, morphological and archaeological evaluations.

Grave No.	Age at death	Genetic approach	Morphological approach	Grave equipments
170	infans I (8 y.)	M	M ?	gold gombic
207	infans II (10-11 y.)	F	?	
260	infans I (2 y.)	F	F ?	
315	infans I (3-4 y.)	F	? (F ?)	
424	infans I (7-8 y.)	M	M	silver earring, silver gombic
431	infans II (8-9 y.)	M	M ?	silver gombic, knife
460	infans I (2-3 y.)	M	M ?	
462	infans I (4-5 y.)	M	? (F ?)	
477	juvenis (14-16 y.)	M	?	knife, calcar, bronz earing
489	infans II (8-9 y.)	M	M	knife
491	infans I (2-3 y.)	F	M ?	2x silver gombic
513	infans I (1,5-2 y.)	M	?	
539	infans I (2-3 y.)	F	M ?	
543	infans II (8-9 y.)	M	M ?	
597	infans I (4-5 y.)	M	M ?	
619	infans II (8-9 y.)	M	M	
621	infans II (8-9 y.)	M	M ?	
623	infans I (2-3 y.)	F	? (M ?)	
638	infans I (2-3 y.)	M	M	
644	infans II (10-12 y.)	M	M ?	knife
658	infans I (6-7 y.)	M	M ?	
745	infans II (9-10 y.)	F	?	
979	infans I (6-7 y.)	F	F ?	
1124	infans II (10-11 y.)	F	F	
1127	infans II (7-8 y.)	M	? (M ?)	
1158	infans I (4-5 y.)	M	? (M ?)	
1235	infans II (12-15 y.)	M	M ?	
1463 a	infans I (4 y.)	F	? (M ?)	
1509	infans II (7-8 y.)	M	? (M ?)	
33/IV	infans II (12-15 y.)	M	? (M ?)	
39/IV	infans II (12-15 y.)	F	? (M ?)	knife
41/IV	infans I (5-6 y.)	F	M	
64/VI	infans II (12-15 y.)	M	M ?	calcar, strap-end
121/VI	infans II (7 y.)	M	M	calcar, little knife (iron)
140/VI	infans II (8-9 y.)	M	?	
160/VI	infans I (6-7 y.)	F	F ?	4x earring (gold), 2x earring (silver), gombic (silver), bucket, little knife
167/VI	infans I (1-2 y.)	M	M ?	

? – non determinable, ? (M ?) or ? (F ?) – non determinable-ambiguous sex, M – male, M ? – more likely a male, F – female, F ? – more likely a female, y – years

The sex of five adult skeletons was evaluated on the basis of the morphoscopy (Bruzek 2002) and metric characteristics of pelvic bones (so-called primary sex diagnosis) (Murail/Bruzek/Braga 1999; Murail et al. 2005). Besides that, sex was also determined with the help of discriminating functions based on cranial measurements (secondary sex diagnosis). These functions were derived from the Great Moravian population (Brůžek/Velemínský 2006).

3. Results

The results of the primary and secondary morphological analysis as well as the molecular genetic analysis of the five adult skeletons are presented in Table 1. In all five adult samples, the sex data of the genetic and morphological approaches matched precisely (100% concordance). This result allowed us to apply the same genetic procedure to the group of 47 sub-adult individuals.

In 37 out of 47 ancient teeth samples (78.7%), the extraction aDNA was successful (it yielded amplifiable aDNA). The sex of each individual is shown in Table 2. We obtained results for 24 males and 13 females (a male to female ratio of 1.85:1). When there was no PCR product after the first amplification, the use of a smaller amount of DNA in the PCR reaction sometimes helped. The second round of extractions in particular yielded detectable amounts of aDNA compared to no product detection in the first round.

On the basis of the morphological characteristics of the iliac bone and mandible, we determined the sex for 23 out of 37 genetically sex-determined skeletons (62.2%). For the remaining 37.8% of the sub-adults, the morphological sex traits were equivocal (see Table 2). In nine cases we did not determine the sex affinity, even though one of the sexes is more probable according to the morphological characteristics (e.g. ? (M ?) or ? (F ?)). The sex determination of some individuals was also limited by skeletal preservation. Likewise, in the case of genetic analysis, the results showed a uniquely higher presence of male sub-adult skeletons. We recorded the presence of 19 males and four females.

When the sex of an individual was genetically determined, it was compared with the morphological sex estimate (Table 2). The concordance between genetic and morphological determination of sex was high (87%). There was disagreement in only three out of 23 skeletons (graves No 491, No 539 and No 41/IV). However, when the morphological approach was based on the iliac bone and mandible separately, a different concordance was achieved (83.3% and 73.9% respectively). Although the reliability of morphological methods is low due to the low degree of sexual dimorphism in immature skeletons, we recorded an unexpectedly high concordance between both applied approaches. We consider the value of the coincidence (87%) as a rather random result. The concordance obtained on the basis of separate morphologic approaches (iliac bone and mandible) is approximately 60%-90% (e.g. Schutkowski 1993; Weaver 1980), which appears more realistic (Lewis 2007).

In some sub-adult graves from the Mikulčice cemeteries included in this study, grave goods attributed to females or males was found (e.g. Hrubý 1955; Stloukal 1970). Only a few records of grave goods exist for our 23 morphologically studied samples. Particular grave goods are also listed in Table 2.

4. Discussion

4.1 Genetic approach

To test the reliability of the method for genetic sex analysis that we applied, we first worked with a test group of five adult individuals with distinct morphological traits. Amel80/83bp and DYZ1/102bp PCR systems provided sufficient information about genetic sex for all of the studied subjects. A comparison of the genetic data and morphological data revealed 100% concordance. Although the number of studied adult individuals is very low. We presume that the very high concordance obtained is not a result of random matching . This observation of the five adult individuals proved the reliability of the applied genetic procedure and the authenticity of the aDNA studied.

Subsequently, we genetically analyzed 47 sub-adult individuals from the 9th century cemetery. All the samples underwent an identical procedure to the five samples of adult individuals. We were able to record the sex of 37 out of 47 examined sub-adults. In those 37 samples it was possible to isolate aDNA and to apply an optimized PCR protocol to obtain DNA fragments containing sex information. The successful analysis rate of 78.72% is lower than in our prior study (94.7% in (Bromová et al. 2003)), but higher than in several other studies (Faerman et al. 1998; Gotherstrom et al. 1997; Mays/Faerman 2001) – 28.5%, 44% and 42% respectively.

There are several possible explanations for the unsuccessful aDNA isolation rate of over 20% (10/47). Most probably, the aDNA material was degraded to such an extent that no fragments of corresponding length could be amplified. Secondly, the process of isolation could have been successful, but substances that inhibit the elongation step during PCR amplification may have been present as a co-extract (Kemp/Monroe/Smith 2006). Different amounts of aDNA template in a PCR reaction sometimes help overcome this problem. Finally, specimen-specific attributes (for example sequence mutation at the site of primer annealing) could have blocked the correct amplification procedure.

In previous years, some scientists have developed methods that could ascertain whether a specific specimen is suitable for aDNA analysis. The extent of amino acid racemization is one such tool (Poinar et al. 1996). This method is very labour-intensive, expensive and time consuming and some authors suggest that it may not be accurate since amino acid racemization and DNA degradation could have different kinetics in bones (Collins/Waite/van Duin 1999). The histological preservation of bones seems to be a better method, although it also has some drawbacks. Even bone samples with outstanding histological parameters are not ideal for aDNA analysis (Haynes et al. 2002). However, some authors have obtained 100% concordance between histological preservation and success of DNA amplification (Colson et al. 1997). This process is also very labour-intensive and, according to some studies, not as accurate. When sub-adult bone specimens were analyzed for concordance between specific histological preservation and success of aDNA amplification (Colson et al. 1997), it was shown that one bone specimen from the group with less preserved histological parameters was also very weak at aDNA amplification. An important point is that this was one from a total of five successful amplifications out of seven specimens, and even low histological preservation allowed aDNA amplification. The grouping of bones for aDNA analysis according to histological examination could, for that reason, be very inappropriate.

As to aDNA isolation, a second round of extraction from the same bone powder usually increased the aDNA yield to a detectable level. We presume that in the second and following isolation, the number of protein and other co-extracts (Hagelberg/Clegg 1991) decreases, and amplification is thus not inhibited. Similar results have been obtained by Kemp (Kemp et al. 2006). We have experienced how difficult it may be to establish an optimized PCR protocol for the detection of low amounts of degraded aDNA. When the aDNA concentration was diluted, this sometimes helped us to obtain amplification products. Inhibitory substances were probably present in many specimens.

Allelic drop-out was frequent among our specimens. When the Y-amelogenin locus did not amplify, the resulting band of the X-amelogenin locus appeared to originate from a female individual (see figure 1). We also amplified the aDNA on DYZ1. This system was better optimized, gave results for more specimens than Amel80/83bp and determined all male individuals. Similar results were obtained in a work by Ovchinnikov (Ovchinnikov et al. 1998). In their study they used the amelogenin sexing system Amel106/112bp (Sullivan et al. 1993), which was successful in only 25% of samples, as well as the DYZ1 system, which was better optimized. Since Amel80/83bp focuses on shorter sequences than Amel106/112bp, it is advisable to use it for aDNA sexing analysis.

It was apparent that a higher number of PCR cycles was needed when aDNA was amplified. Recent studies have shown that the amount of aDNA starts to rise after the 25th cycle (Kefi et al. 2003). Our amplification profile consists of 35 to 40 cycles on average.

The protocol developed for our study seems to be a very useful tool for sex analysis. It is easily recognizable from primer-dimer formation, which was always up to 70bp long.

4.2 Morphological approach

Using skeletal morphology it was possible to estimate the sex of 23 sub-adults (19 male and four female), approximately 60% of genetically determined individuals. Among the remaining 14 sub-adults, sexual morphological traits were ambiguous. Nevertheless, in nine cases (9/37), we could not precisely determine sex, although one of the sexes was, according to morphological characteristics, more probable (e.g. ? (M ?) /? (F ?) – in Table 2). The sex determination from specific morphological markers of some bone remains was also limited by skeletal preservation. In seven individuals the mandible was not preserved, while the iliac bone was not present in two individuals. If we compare the two applied morphological methods (Molleson/Cruse/Mays 1998; Schutkowski 1990, 1993), the concordance in sex determination was 100% (N=17). Whilst the Schutkowski method is based on signs on the mandible and iliac bone, using the method of Molleson /Cruse/Mays (1998) we only applied the signs on the mandible. This concordance is thus not surprising.

A significantly different situation arises if we compare the results of sex determination based on the mandible and iliac bone. Sex was determined concordantly in the case of 11 children (78.6%), while antagonistic sex determination occurred in three cases (i.e. 21.4%). The determined concordance/divergence cannot be generalized due to the small number of cases involved.

It appears that sex determination based on the structure of the iliac bone has a greater predicative value. This, though, may be affected by the worse preservation of the mandible in the studied group. On the other hand, sex determination using the mandible is based on multiple signs, meaning that the subjective view of the researcher plays a relatively smaller role. With regard to the size of our group and the number of children in our study, neither the bones nor any of the methods applied may be considered ideal for sex determination.

The reliability or accuracy of sex morphological methods in sub-adults mostly varies from approx. 60% to 90% (e.g. Mittler/Sheridan 1992; Schutkowski 1993; Weaver 1980). Moreover, a different accuracy of determination was reported between males and females (e.g. Mittler/Sheridan 1992). The age of a child's skeleton may also play an important role – it follows that the age used to draw up the relevant methods may be an important factor (see Lewis 2007).

4.3 Comparison of genetic and morphological approaches

The sex information from the genetic analysis was taken as a standard. The results of such determination were not known prior to the qualitative evaluation of the morphological traits. This criterion helped us to avoid the subjective factor from interfering with the results of the morphological approach. We were able to record the sex of sub-adults using morphological methods in 23 out of 37 genetically characterized individuals. We monitored the concordance of the obtained data for the 20 identified sub-adults. Surprisingly, there was 87% concordance (20/23). There was disagreement as to the recorded sex for only one sub-adult.

The morphological method itself was not given high credibility by the anthropologist. However, these results provided very interesting evidence for the appropriate application of the Schutkowski (Schutkowski 1990, 1993) and Molleson (Molleson/Cruse/Mays 1998) methods on sub-adult bones for sex determination. The probability of a random match among all 21 individuals is very low.

If we compare the determination on the basis of individual bones with genetically determined sex, in the case of the iliac bone, sex was determined concordantly in 83.3% of the children (20/24), and on the mandible, the sexual signs corresponded to the genetic determination in 69.6% of cases (11/14; method by Schutkowski), in 73.9% of the children (16/23; method by Molleson) respectively.

It thus appears that sex determination based on the structure of the iliac bone has a greater predicative value.

The very low number of samples studied may interfere with this high (87%) success rate. The data for morphologically identified sub-adults was recorded as a summary of all the evaluated morphological traits on the pelvic bone and mandible. The value of concordance of both approaches obtained on the basis of the two morphological methods separately reached a value of approximately 65% to 90%. This value of concordance resembles the standard success rate (e.g. Lewis 2007).

Several earlier studies also focused on the issue of comparing sexing results obtained using genetic and morphological approaches (Ovchinnikov et al. 1998; Waldron/Taylor/Rudling 1999) etc. Different morphological methods were applied and so it would be inappropriate to compare the success rate of genetic versus morphological data. However, these studies imply the necessity of a multidisciplinary approach.

All the morphological sex determination techniques have been based on the study of contemporary populations. For correct application, the characteristics analyzed should be calibrated to the population examined (Vernesi et al. 1999). In our group from the 9th century, it is apparent that it was possible to apply morphological techniques without losing correct information. This is possible to deduct (with some exaggeration) from high sex determination agreement of different methods of evaluation.

The higher number of male individuals in our sample is surprising. We uncovered almost twice as many males as females – 24M:13F in the genetic and 19M:4F in the morphological approach. This ratio could have been influenced to a certain extent by the selection of the children evaluated. Most (two thirds) of the evaluated children were buried on the grounds of the Mikulčice castle itself (N=28), and only one third came from the surrounding settlement. If we were to speculate that individuals of male sex in the Early Middle Ages held a more important social position, then in the castle we would expect to find a greater proportion of graves containing the remains of boys rather than girls. If we look at the current paleo-demographic studies of the Mikulčice cemetery, then it is clear that males predominate within the grounds of the castle, while women predominate in the surrounding settlement. As to the age structure, older individuals were buried mainly in the castle, while the graves of non-adult individuals had a higher representation in the settlement. For example, the so-called "index of representation of non-adult persons" is 75.2 in the castle and 84.3 in the settlement (Stloukal 1989; Velemínský et al. 2005). On the social ladder, small children were probably not considered to be "fully fledged" individuals. But we must take into consideration the unresolved paleo-demographic issue – namely the absence of children under two years of age. The demographic conclusions, though, do not definitely exclude the presumed more frequent burial of boys in the castle. We may speculate that if a child were buried in the castle, it would probably have been a boy.

On other hand, we can also speculate that boys had a lower chance of survival during childhood. The demographic mortality curve of children from Mikulčice castle and estates, though, follows a similar course, with no significant fluctuations, and it begins falling steeply only after the tenth year of life. This reflects the natural mortality of the population of children. Finally, the higher proportion of boys may also be explained by the different state of preservation and conservation of the mandible and pelvic bone in both sexes.

The suggestion that sub-adult male skeletons may be better protected from environmental factors due to the higher inorganic fraction in their bones (DNA seems to bind to hydroxyapatite structures (Burger et al. 1999) is refuted by the fact that some older individuals have no amplifiable aDNA (g.n. 481,643) when compared to very young ones (g.n. 513,167/VI), whose inorganic fraction is remarkably lower. In this manner, more male specimens could have been classified as sub-adults.

In a study by Lassen (Lassen/Hummel/Herrmann 2000), individuals found in Aegerten in Switzerland also presented a disproportion between male and female individuals. In this work, only stillborn and neonatal individuals were studied and the disproportion was explained by the higher mortality of males from the last months of pregnancy until six months after birth (Eiben et al. 1990). In our study, the sub-adult individuals had a life span from birth to 12 years of age.

The possible socio-cultural reason for the higher representation of male individuals will be studied further. However, random sampling of sub-adults from different regions of the Mikulčice cemetery tends to exclude any socio-cultural reason. This subset of sub-adult individuals is unfortunately too small for the use of statistical methods.

Limited archaeological records of grave goods have also been included in Table 2. Records are available for 10 of the 23 morphologically determined individuals, although their low number precludes systematic evaluation. Identical genetic, morphological and "archaeological" determination of sex was found in the case of three graves (graves No. 64/VI, 121/VI and 160/VI), if we accept the fact that specific grave goods are attributed strictly to individuals of certain sex (Hrubý 1955). Agreement between multidisciplinary approaches favours the usefulness and correctness of the methods applied.

Our extracts were free of exogenous contaminating DNA, as we can deduce from the system of blind controls and the high percentage of sex determination agreement between morphologic and genetic data among adult individuals. According to some findings (Kolman/Tuross 2000), blank controls without product amplification do not signify that contamination was absent in other tubes.

5. Conclusion

This study focused on developing a protocol for aDNA sex analysis from sub-adult archaeological bone remains. aDNA was successfully analyzed in 37 out of 47 sub-adult individuals. The laboratory-developed protocol proved to be a very powerful tool for sub-adult sex determination. This approach was very successful for sex determination in a majority of samples. The results obtained served as a standard for comparison with the results of specific morphological approaches, similarly to grave goods records. The Schutkowski and Molleson morphological methods proved to be applicable, but provided data for a significantly lower number of samples. Their advantage lies in the low cost of analysis. The study group in question will serve as a standard for ongoing research focusing on the development of new morphological methods for the sex determination of sub-adult skeletons. Our contribution shows the value of the simultaneous application of different approaches as the best tool for objective evaluation.

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Anthropological and epidemiological characterization of Great-Moravian population in connection with the social and economic structure

Stature of the Great Moravian Population in Connection with Social Status

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Stature is one of the basic anthropometric information relating to man. It reflects very sensitively a number of factors such as e.g. living conditions, sex, age, ethnicity, etc. We were mainly interested in the relationship between stature and living conditions that in each historical period are significantly influenced by social class. We compared the skeletons from the Mikulčice highest social class with skeletons from the area below the castle and from distant areas that represented the background of the first two groups. Subsequently, we compared the Great-Moravian population with recent statures acquired at the end of the 20th century.

Key words: stature – social status – Great-Moravian population – recent population

1. Introduction

Determination of stature in living persons as well as its calculation from skeletal remains has long been enticing thanks to the fact that height very sensitively reflects a number of factors such as sex, age, ethnicity, social standings, etc. Stature aids in assessing the medical condition, body proportions and body dimensions in association with living conditions in the widest sense of the word. Height, together with weight form part of the basic parameters used to estimate population nutritional and health status. Thus stature becomes one of the important signs that enable the characterisation of both individuals as well as whole populations. Determination of stature is one of the most basic anthropometric figures. This also holds for the Great-Moravian populations that are the subject of our research.

Stature is defined as the perpendicular distance between the vertex anthropometric point and the ground (Martin/Saller 1957). The definition is simple, but the interpretation of concrete assessments is not without pitfalls. It is commonly known that stature changes during the day; it is greatest immediately following a night's rest and decreases rapidly. This decrease is chiefly due to the compression of inter-vertebral discs and the soft sections of the heel. During the day, man loses around 2 cm of his height, and this loss is greatest 6-7 hours following the assumption of the permanent or long-lasting position. A two-hour rest period, though, can again increase stature by one centimetre. Other changes in height are associated with age. Approximately from the age of 30, height gradually decreases due to the influence of "wear and tear", ageing of the organism (Ousley 1995). Nonetheless, the daily fluctuation of height may be greater than the loss associated

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with age (Sjøvold 1990). Deliberations regarding measurement and changes in height with daily fluctuation and fluctuation during the life cycle become important when attempting to estimate the stature of a living human being from its skeletal remains, as the validity of the data acquired when creating a reference group may significantly influence precision of the estimate.

The important components of stature diversity in individuals as well as populations include genetic differences, yet living conditions also play an important role. Silventoinen et al. (2003) when comparing eight populations (Australia, Denmark, Finland, Italy, Holland, Norway, Sweden and Great Britain) found the shortest stature to be associated with Italians, i.e. height was associated with a specific population in which certain family affiliations existed. Overall stature is the sum of the length (height) of body segments and the inter-population differences in height may be affected by the various relationships between them (Kozak 1996). The issue of the degree of influence of climate and thermoregulation on physical proportionality has also not been resolved. The results of studies published to-date are rather conflicting (Feldesman/Fountain 1996).

Living conditions have a significant effect on stature, as shown e.g. by Maat (2005). Capitularies from the Maastricht basilica (1070-1521) were 3.4 cm taller than the rest of the population whose life was probably less comfortable than that of the capitularies. Maat also mentions the work of Zeeman (1861) who studied the height of military recruits over a period of 27 years and found that fluctuation of their height copied with some delay the "evolution" of the price of the main foodstuff of that period, rye. Similar results regarding the relationship between stature and economic cycles were also published two years earlier by Woitek (2003) or Cole (2003). Gunnell/Rogers/Dieppe (2001) states that the length of bones and thus stature is also associated with the risk of premature death; the taller the individual, the lower the risk is. It has been shown that for death before the age of 30, extension of bones by a single standard deviation from the average length is associated with a 10-20% decrease in the risk of premature death. Many such examples can be found in literature.

Calculations are also complicated by the secular trend, either positive or negative. To date, the question whether changes in stature are proportional or whether they are more affected by changes in the proportions of body segments, e.g. the length of the femur or tibia has not been resolved.

Regression formulas are usually calculated independently for each specific population and separately for males and females. Differences between reference groups are usually statistically conclusive and thus it is not suitable to apply the calculated formulas for another population than for that for which they were calculated. These differences are given, as mentioned before, by genetic factors, living conditions, age distribution as well as techniques of measurement, methods of statistical processing etc. And if we have skeletal remains of unknown origin, the differences between regression formulas are misleading. Sjøvold (1990) has attempted to avoid this by formulating a method for determining height that is applicable regardless of sex and ethnicity. This is based on the fact that all formulas for calculation of stature include information relating to the height: length ratio of long bones and that this ratio is practically independent of sex and ethnic origin. Despite Sjøvold's precise mathematical reasoning, his method has not as yet come to be widely used in concrete cases for various reasons.

The long bones of the limbs are considered to be the most reliable components of the skeleton for the calculation of height. Kurth (1954) in his work recommends that stature be calculated as the arithmetic average of measurements of the humerus, radius, femur and tibia from both sides of the body. This procedure cannot be applied in many cases, as the given bones have not, simply put, been preserved.

Along with the length of long bones, stature has been determined with the aid of other components or fragments of the skeleton. For example, we can mention the work of Steele (1970) and Steele/McKern (1969) relating to fragments of long bones of lower limbs, Musgrave (1978) relating to the length of metacarpal bones, Mysorekar/Verma/Mandedkar (1980) relating to fragments of the femur and radius, Dobisíková/Urban/Strejc (1988) relating to the length and width of the skull, Holland (1992, 1995) relating to fragments of the tibia, calcaneus and talus Jacobs (1992) relating to fragments of the tibia and femur, Meadows/Jantz (1992) relating to the length of the metacarpal bones, Jason (1995) relating to vertebral segments and others. Similar works though are mainly used in forensic practice; for historical skeletal remains they are used only as auxiliary methods in the identification of concrete persons when long bones have not been preserved. For population studies, they are not useful due to the smaller correlation of dimensions with length. Currently, formulas based on the length of the femur are most widely used as this has a direct effect on stature and is frequently preserved.

Correctness of the calculation of "live" height is also significantly affected by whether the values of the reference group were acquired from measurements of living persons or measurements taken during autopsy. In a dead body, the muscle tone changes and curvature of the spine straightens. Thus the body extends by approximately 2-2.5 cm (Černý 1961). It must be remembered that "body height" is calculated using methods with a reference group represented by living persons, while methods using a reference group consisting of autopsy data provide information regarding "body length". When selecting methods, we must thus respect the means by which the reference group was obtained and conduct eventual corrections.

Attempts at scientific determination of stature from skeletal remains date to the first half of the 19th century. In 1831, M. Orfila drew up the first tables based on the length of the long bones of limbs. Among his successors, we could name Humphry in England in 1858 (Černý 1961), Langer in Austria in 1872 (Černý 1961) and Toldt from 1882 (Černý 1961). More precise results than the works of the aforementioned authors were based on the coefficient of the relationship between the height and length of long bones, calculated by Topinard in 1885. He respected the differences between males and females. The regressive formula for the calculation of stature from the length of the femur was created in 1888 by Beddoe (1888). Though these and other works tried to resolve this problem, they were mostly based on a small amount of material and thus they were greatly imprecise.

The turning point in the development of methods for the reconstruction of stature from skeletal material was represented by the work of Rollet from 1889. Rollet created on the basis of the examination of the skeletons of 50 males and 50 females so-called synoptic tables, according to which stature could be determined. In his work, though, he made the same mistake as his predecessors. He determined the average length of the long bones of persons with the same height. Bertillon (Telkkä 1950) though found in a group of 150 males and females of the same height, that equally tall people need not have lower limbs of the same length. Moreover Rollet conducted measurements on bones without maceration, and thus 2 mm must be added to the measured length of the dry bone. This correction was introduced following the discovery that upon desiccation, the length of bone shortens by this precise extent. Many other authors of further calculations based their work on Rollet's material, Manouvrier (1892, 1893), Pearson and Lee (1897) and Pearson alone (1899). Pearson's and chiefly Manouvrier's tables were still recommended and used by certain researchers in the second half of the 20th century.

The length of bones of Rollet's group was assigned to the length of the dead body measured at autopsy. This fact was later criticised, especially for the specificity of the autopsy material that did not guarantee random selection. It included to a large extent lower social ranks whose height is usually lower than that of social ranks living in comfort. Moreover, the group was drawn up from southern France whose inhabitants are not of great height. Another problem was the relationship between the actual height of the live body and the length of the long bones of the limbs from which the height was calculated. As mentioned previously, after the age of 30, stature decreases due to wear and tear affecting mainly the inter-vertebral discs and joint cartilage and the ratio between stature and bone length changes. This fact, though, was not respected. Nor is the change in muscle tone of the dead body and the straightening of the spine's curvature negligible. Though this was resolved by Manouvrier by subtracting 2 cm from the calculated stature and eliminating persons over the age of 60 from the reference group, methodical deficiencies of his method were still criticised. Dissatisfied with the tables of Rollet and Manouvrier, more and more researchers attempted to calculate stature using their own methods.

In the 1930s, Breitinger (1937) devised anew formula for calculating height, based on measurement of living persons and of the length of long bones determined with the aid of X-rays. This method too, has its pitfalls, as the determination of bone length in this manner cannot be as precise as direct measurement. This imprecision, though, was outweighed by the size of the group that included 2428 German athletes and students as well as by the fact that the true height of living persons was determined as opposed to the length of corpses. This method, unfortunately though, related only to the males section of the population. Formulas for females were not worked out, and the underlying data were burnt during the II^nd^ World war (Černý 1961). Formulas for females were completed by Bach (1965) using a group of female students from Jena. Both Bach's and Breitinger's tables included groups of young people in whom height did not decrease with age or this decrease was only minimal. Calculations according to the formulas of these two authors thus illustrate the true stature of adults who have reached the end of their growth period.

For the taller northern populations, Telkkä (1950) drew up his formulas on the basis of Finnish autopsy material. For the Afro-American and Caucasian American populations, Dupertius and Hadden drew up theirs in 1951. The material of the latter was based on the measurement of the "height" of dead bodies, hung on rods inserted into their ears. They assumed that this height would be identical to that of the live body, and they could thus avoid the issue of differences between the height of the body (stature) and the length of the body. In 1959, though, on revising this methodology Valšík pointed out that not only do the differences between live and dead bodies not decrease, but they actually increase, so that the difference is not the usually contemplated 2-2.5 cm, but greater by another 2.57 cm.

In 1952, Trotter and Gleser drew up a regression formula based on the measurement of great quantities of material from skeletons of American soldiers who died during the II^nd^ World War. This group already reflects the change in stature during life by subtracting the factor f=0.06 (age in years-30), which was included in the formula. In 1958, these authors reconstructed their formulas for men on the basis of material from skeletons from the Korean War. Trotter's and Gleser's formulas for the calculation of stature are most probably the most widely used worldwide. Nonetheless, especially those formulas drawn up for women have been criticised recently (e.g. Jantz 1992) for their unreliable results.

An interesting selection of bones was incorporated in the formulas of Fully (1956, 1960), who included the height of vertebral bodies as an important component of stature. Acquiring data for Fully´s method is quite difficult, though, as it presumes that the vertebral bodies are intact and this is not too frequent the case in historical material. Moreover, the measurement itself demands great experience.

We could continue in this enumeration of works dealing with stature, including both newer (e.g. Porter 1999, Medonca 2000) as well as older publications (e.g. Lorke/Munzner/Walter 1953-1954; Rother 1978; Olivier et al. 1978; Boldsen 1984), that are more or less known.

In Czech literature, by the end of the 20th century, only Černý and Komenda (1982) worked out a method for determining height from the bones of the Czech population. Their reference group, though, is burdened by the same mistake as that of Rollet. The authors based their data on autopsy material that was gathered mainly at the beginning of the 20th century and consisted chiefly of the population of poor districts of Prague.

This flaw was avoided by the authors (Dobisíková/Velemínský/Zocová 2000; Dobisíková et al. 2000) in their second study relating to the calculation of stature and height using the long bones of limbs in the population of the Czech region and by putting together a group of femur and humerus from both sexes using material from forensic laboratories. In view of the indications of forensic autopsies, these bones may be considered to be a randomly selected sample of the population. The length of the body was measured at autopsy, once the body was placed in a natural position, as the distance to the vertex from the intersection of the tangent of the heel protuberance and the posterior section of the plantar side of the planta pedis. The result of these measurements is not stature but body length.

In 2002, Porter summarised the requirements for a method to determine height/stature as follows:

- The method is described in detail so that it may be used by others
- The reference group is structured according to age, sex and ethnicity
- The size and structure of each subject is measured correctly (either alive or post mortem)
- The method enables one to estimate deviations in the calculation
- Measurement of distances is defined; measurements are conducted on intact bones with closed epiphyses
- A measured side is selected (either one or the average from both)
- Mesurement inaccuracy and the correct choice of statistical measurements are counted.

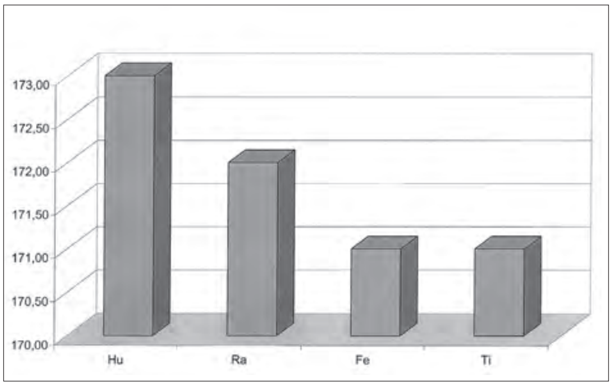
According to the author, these requirements are best met by the methods of Fully (and Fully and Pineau), Breitenger and Bach, Trotter and Gleser and Feldesman (Porter 2002).

From the text above, it is clear what an important role is played by the reference group in the calculation of stature. Such a group may be formed only by a population about which we have sufficient information and basically, without exception, must include a current population. Application of regression formulas drawn up on the basis of recent groups is hampered by the impossibility of verifying the reliability of the calculated data on a historical population. Interpretation of the acquired data may thus be controversial. Thus, e.g. use of Trotter's and Gleser's formulas drawn for use in Palaeolithic skeletons is not met with understanding (Formicola 2003). According to Rösing (1988) various methods of calculation should be applied to various social and economic groups. He recommends Pearson's method (1899) for groups of the lowest economic development, methods of Olivier et al. (1978) for the middle groups and Trotter's and Gleser's method for the group with the best conditions.

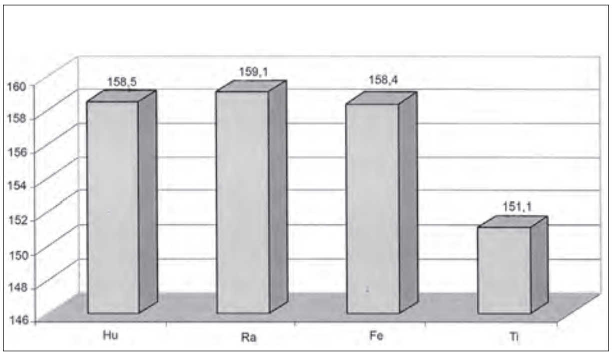
In our opinion, though, the point is not to acquire exact, absolute yet unverifiable figures, but to illustrate the relationships between populations.

2. Materials and methods

We were mainly interested in the relationship between stature and living conditions that in each historical period are significantly influenced by social class. The limiting factor was partly the accessibility and quantity of skeletal remains and partly the abundance of archaeological findings according to which it would be possible to stratify the society. These conditions were met by the Great-Moravian population from Mikulčice and its surroundings. We compared the skeletons from the Mikulčice highest social class concentrated around the IInd church (castle) with skeletons from the sub-castle (Mikulčice IXth church, Mikulčice-Kostelisko) and from distant areas that represented the hinterland of the first two groups (Josefov, Prušánky). Subsequently, we compared the Great-Moravian



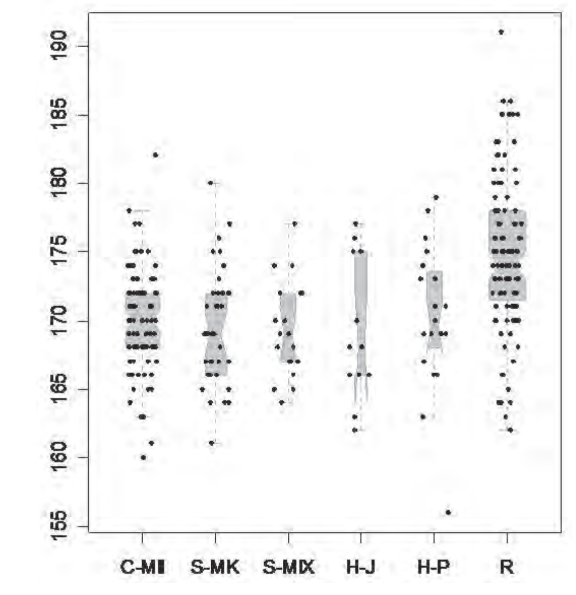
Graph 1. The stature' values of the male from the burial ground Mikulčice-Kostelisko (No. 1821) calculated on the basis different long bones.



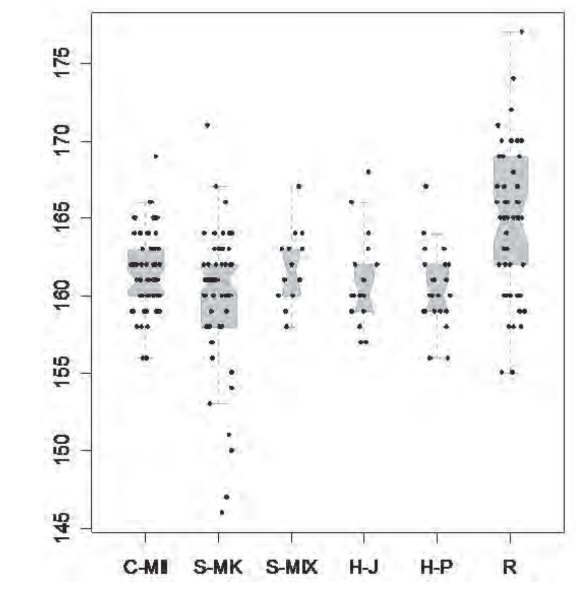
Graph 2. The stature' values of the female from the burial ground Mikulčice-Kostelisko (No. 1899) calculated on the basis different long bones.

population with recent statures acquired at the end of the 20th century (Dobisíková/Velemínský/Zocová 2000; Dobisíková et al. 2000). We used the following abbreviations to designate the individual groups:

In males, stature was calculated using Breitinger's formulas for the femur (Breitiger 1937), while in females, Bach's formula was used (Bach 1965). We chose Breitinger and Bach because since the foundation of the anthropology department at the National Museum, these methods were applied to all groups processed there. At the time, these methods were selected on the basis of testing (Hanáková/Stloukal 1976) and the authors of these tests claimed that Breitinger's and Bach's tables yielded more reliable results then Manouvrier's tables that were used up till then. Although many, e.g. Kurth (1954), Dupertius/Hadden (1951) claim that calculation of stature using a single long bone is less reliable than that using a combination of two or more bones, we kept to the comparison of results using just a single bone. We found this procedure more objective, in view of the various state of bone preservation, despite the fact that Hanáková/Stloukal (1976) claim that the differences in the calculated heights are slightly different using Breitinger's method, while in the case of Bach's method the situation,



Graph 3. Boxplots of stature (in cm), males.



Graph 4. Boxplots of stature (in cm), females.

except for calculations using the tibia that they do not recommend using, is similar.

We chose the femur because its length has the closest correlation with stature (Dobisíková et al. 2000), not only because it is directly involved in stature, but because acquiring its dimensions is easier than measuring other bones whose shapes are more complicated (e.g. the tibia) and they are easily damaged.

For illustration, we include examples of comparisons of stature calculations using various parts of the skeleton for concrete individuals in Graph 1 (males) and Graph 2 (females), with differences for the whole group from Kostelisko in Table 1.

Table 1. Comparison of stature calculations using various long bones of the limbs (S-MK).

	Males	Females
Humerus	171,3	158 ,2
Radius	170,6	159,5
Femur	169,4	160,1
Tibia	170,9	153

3. Results

Statistical evaluation was realised on the base the study Venables/Ripley (2002) and Wilcox (2004), graphical evaluation on the base Murrell (2005). In our study, we tested three basic questions, or more precisely, we verified three zero hypotheses:

Zero hypothesis 1: the stature of the populations from the **castle** (C-M-II), the **sub-castle** (S-M-K, S-M-IX) and the **hinterland** of the Mikulčice agglomeration (H-J, H-P) does not differ from the aspect of sex

Zero hypothesis 2: stature of the **early Middle Age – Great-Moravian population** (Mikulčice, Prušánky, Josefov) does not differ from the stature of the **recent population**

Zero hypothesis 3: there exist no differences in stature between males and females, either in the Middle Ages or today.

The following Table 2 includes the basic characteristics of the individual groups.

The distribution of stature for the individual burial grounds is shown in Graph 3-4. At first glance, it is apparent that the average height of all Great-Moravian groups is well balanced and that they all differ from the recent group. This, though, is not surprising. The Great-Moravian age is situated in a period of a negative secular trend that occurred in Europe approximately from Roman times until approximately the middle of the 19th century. The recent group is situated in a period of a positive secular trend that began in the second half of the 19th century.

Neither here do we see any significant differences. Only in females are the numerical

Table 2a. Basic statistical data of stature according to burial grounds (males).

	C-M-II	S-M-K	S-M-IX	H-J	H-P	Recent
N	89	37	19	12	20	107
minimum	159,530	161,260	164,470	162,330	156,490	162
C minimum	163,000	161,000	164,000	162,000	163,000	162,000
1. quartil(Q)	168,000	166,000	167,000	166,000	168,000	171,500
median	170,000	169,000	169,000	168,000	169,500	174,000
AA	169,876	169,432	169,263	169,333	170,150	174,785
3. quartil(Q)	172,000	172,000	172,000	175,000	173,500	178,000
C maximum	178,000	180,000	177,000	177,000	179,000	186,000
maximum	182,480	180,010	177,220	176,560	178,530	191
SD	3,677	4,180	3,509	5,211	5,294	5,575
LB	169,330	167,442	167,188	163,895	167,557	173,007
UB	170,670	170,559	170,812	172,105	171,443	174,993

Table 2b. Basic statistical data of stature according to burial grounds (females).

	C-M-II	S-M-K	S-M-IX	H-J	H-P	Recent
N	63	61	14	17	23	53
minimum	155,930	146,470	158,230	156,580	155,800	155
C minimum	156,000	153,000	158,000	157,000	156,000	155,000
1.quartil (Q)	160,000	158,000	160,000	159,000	159,000	162,000
median	161,000	161,000	161,500	160,000	160,000	165,000
AA	161,459	160,115	161,786	160,941	160,522	164,943
3.quartil (Q)	163,000	162,000	163,000	162,000	162,000	169,000
C maximum	166,000	167,000	167,000	166,000	164,000	177,000
maximum	168,790	170,960	167,090	167,610	166,560	177
SD	2,507	4,329	2,392	2,989	2,466	4,688
LB	160, 393	160,191	160,233	158,850	159,012	163,481
UB	161,607	161,809	162,767	161,150	160,988	166,519

The statistical analysis used values of the corrected (C) maximum and minimum statures in order to eliminate distant observations (outliers):

N = simple size
AA = arithmetic average
SD = standard deviation
LB = lower limit 95% of interval confidence for the median confidence interval
UB = upper limit 95% of interval confidence for the median confidence interval

C minimum = 1.Q-1,5(3.Q-1.Q)
C maximum = 3.Q+1.5(3.Q-1.Q)

Table 3a. Characteristics of the population groups according to social structure (males). The values used in this table are the same as in the previous one.

	Castle	Subcastle	Hinterland
N	89	56	32
minimum	159,480	161,260	156,490
C minimum	160,000	163,000	161,000
1. quartil	167,000	167,000	168,000
median	169,000	169,000	171,000
AA	169,483	169,839	170,125
3. quartil	172,000	172,500	173,000
C maximum	178,000	180,000	177,000
maximum	182,480	180,010	178,530
SD	3,934	4,455	3,687
LB	168,163	167,839	169,604
UB	169,837	170,161	172,397

Table 3b. Characteristics of the population groups according to social structure (females).

	Castle	Subcastle	Hinterland
N	61	75	40
minimum	155,930	146,470	155,80
C minimum	157,000	155,000	156,00
1. quartil	160,000	159,000	159,500

	Castle	Subcastle	Hinterland
median	161,000	161,000	161,000
AA	161,525	160,080	161,250
3. quartil	163,000	162,000	163,000
C maximum	167,000	164,000	166,000
maximum	168,790	170,960	167,610
SD	2,675	3,972	2,519
LB	160,393	160,453	160,126
UB	161,607	161,547	161,874

Table 4a. Statistical expression of the difference in stature between social classes (males).

	AA diff	LB	UB	TS	SE	p-val	GTS	gp-val
castle-subcastle	0,064	-2,507	2,634	0,058	1,100	0,953		
castle-hinterland	0,812	-1,914	3,538	0,696	1,166	0,509		
subcastle-hinterland	0,748	-0,831	2,328	1,107	0,676	0,280	0,646	0,464

AA diff difference of the arithmetic averages (estimate of the differences of the median values)
LB lower limit 95% of interval confidence for the median confidence interval
UB upper limit 95% of interval confidence for the median confidence interval
TS Yuen-Welch t-statistics for testing the difference of mean values (based on trimmed means and winsorized variances)
SE standard error
GTS global Yuen-Welch t-statistics (TS for 2 and more differences)

Table 4b. Statistical expression of the difference in stature between social classes (females).

	AA diff	LB	UB	TS	SE	p-val	GTS	gp-val
castle-subcastle	-0,881	-2,103	0,342	-1,714	0,514	0,092		
castle-hinterland	-0,606	-1,793	0,582	-1,213	0,499	0,230		
subcastle-hinterland	0,275	-1,004	1,554	0,512	0,538	0,614	1,585	0,210

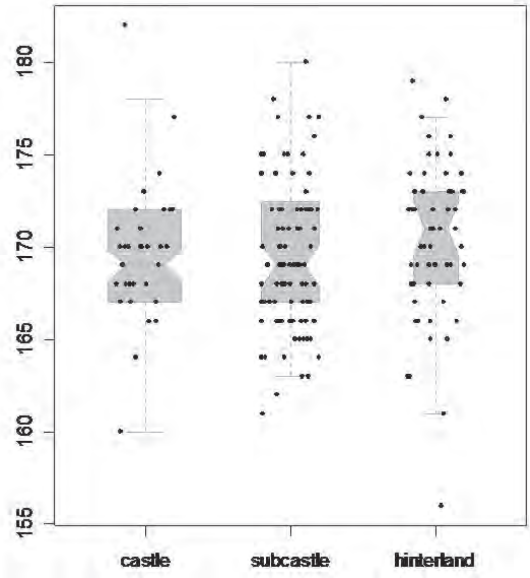
Table 5. Comparison of the Great-Moravian population and recent population on the basis of stature.

		AA diff	LB	UB	TS	SE	p-val
middle age-recent	males	-4,944	-6,256	-3,631	-7,442	0,664	< 0,001
	females	-4,041	-5,555	-2,525	-5,195	0,778	< 0,001

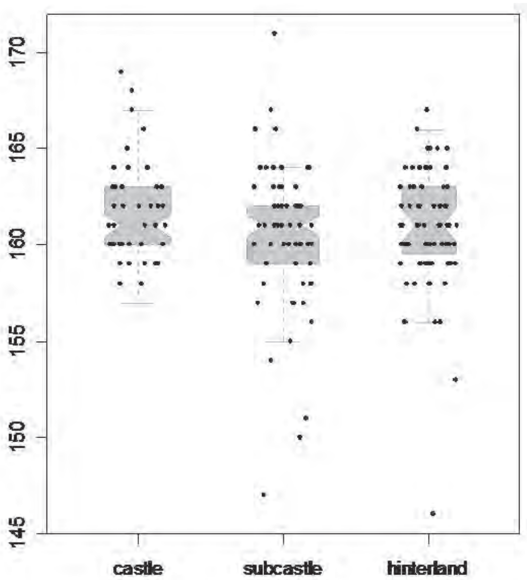
Table 6. Statistical differences in stature between the sexes.

	AAdiff	LB	UB	TS	SE	p-val
middle age(m-f)	8,589	7,827	9,351	22,363	0,384	< 0,001
recent (m-f)	9,493	7,614	11,372	10,015	0,948	< 0,001

AAdiff difference of the arithmetic averages
LB lower limit 95% of interval confidence for the median confidence interval
UB upper limit 95% of interval confidence for the median confidence interval
TS Yuen-Welch t-statistics for testing the difference of mean values (based on trimmed means and winsorized variances)
SE standard error



Graph 5. Boxplots of stature (in cm), males.



Graph 6. Boxplots of stature (in cm), females.

Table 7. Categorisation of the stature range (males, females).

Males		Females
130-149,9	very small	121-139,9
150-159,9	small	140-148,9
160-163,9	below medium	149-152,9
164-166,9	medium	153-155,9
167-169,9	above medium	156-158,9
170-179,9	tall	159-167,9
180-199,9	very tall	168-186,9

values of height smaller than in males, their distribution is narrower and thus the height is more homogenous. The statistical expression of the relationship between social class and stature is shown in Table 4. The graphical depiction of the comparison of stature between the highest social rank, the area below the castle and the background is illustrated in Graph 5-6.

If we compare the Great-Moravian population, where there is no significant difference either between the various locations or between the social groups, with the recent population, we get at the level of $\alpha = 0.01$ very significant differences, in both sexes. This is shown in Table 5 and Graph 7-8.

Another studied parameter was the comparison of the height of males and females. As no differences were found between the Great-Moravian groups, we include an overall comparison of males and females from the Great-Moravian period with the recent population in Table 6 and Graph 9-10.

The statistically significant difference between the height of males and females is at the level of $\alpha=0.01$ both in the Middle Ages and in the recent population.

To compare the distribution of height in the individual groups, we used the method of height categorisation devised by Martin and Saller (1957). We include this traditional distribution despite the fact that we currently have different ideas about "tall" stature thanks to the positive secular trend. This classification has long been used and it can thus be applied when comparing older groups, where no valid statistical parameters are mentioned.

In males and females of all groups, the category of tall stature is represented most frequently. The differences in the representation of the other categories are not great, with the exception of the recent population where very tall stature is significantly represented.

When looking at the table showing the representation of individual stature categories in three different social classes, the previously stated more homogenous height in females is clear. We can say that the majority of females of the studied Great-Moravian population were tall. Most of the tall females were found among the highest social class. The fewest number of tall females was among the group from below the castle. In males, this trend is practically similar, although it is less pronounced given the wider range of stature. The possible explanation is that the inhabitants of the background, mainly agriculturists who include a larger proportion of tall statures compared to the craftsmen from below the castle, may have had easier access to food that they cultivated and thus had less problems with nutrition.

Table 8a. Representation of the stature categories in the individual groups according to burial grounds (males).

	C-M-II		S-M-K		S-M-IX		H-J		H-P		Recent	
	n	%	n	%	n	%	n	%	n	%	n	%
very small	-	-	-	-	-	-	-	-	-	-	-	-
small	-	-	-	-	-	-	-	-	1	5,0	-	-
below medium	4	4,5	1	2,7	0	0	2	16,7	1	5,0	2	1,9
medium	11	12,4	9	24,3	4	21,1	3	25,0	2	10,0	6	5,6
above medium	25	28,1	11	29,7	7	36,8	2	16,7	6	30,0	6	5,6
tall	48	53,9	15	40,5	8	42,1	5	41,7	10	50,0	71	66,4
very tall	1	1,1	1	2,7	-	-	-	-	-	-	22	20,6

Table 8b. Representation of the stature categories in the individual groups according to burial grounds (females).

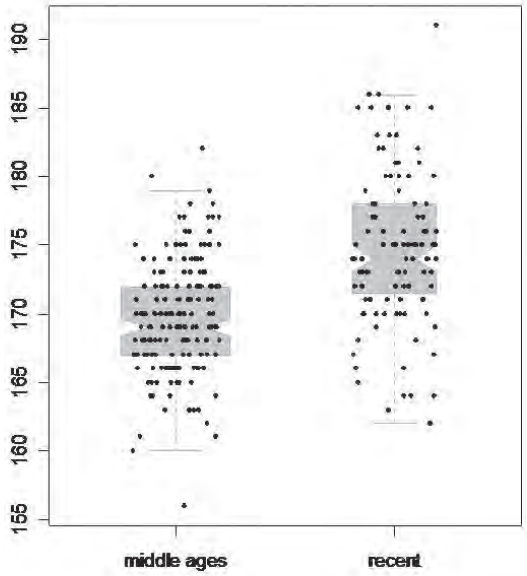
	C-M-II		S-M-K		S-M-IX		H-J		H-P		Recent	
	n	%	n	%	n	%	n	%	N	%	n	%
very small	-	-	-	-	-	-	-	-	-	-	-	-
small	-	-	2	3,3	-	-	-	-	-	-	-	-
below medium	-	-	2	3,3	-	-	-	-	-	-	-	-
medium	-	-	3	4,9	-	-	-	-	-	-	2	3,8
above medium	5	8,2	9	14,8	1	7,1	3	17,6	3	13,0	3	5,7
tall	55	90,2	44	72,1	13	92,9	13	76,5	20	87,0	33	62,3
very tall	1	1,6	1	1,6	-	-	1	5,9	-	-	15	28,3

Table 9a. Representation of the stature categories according to social class (males).

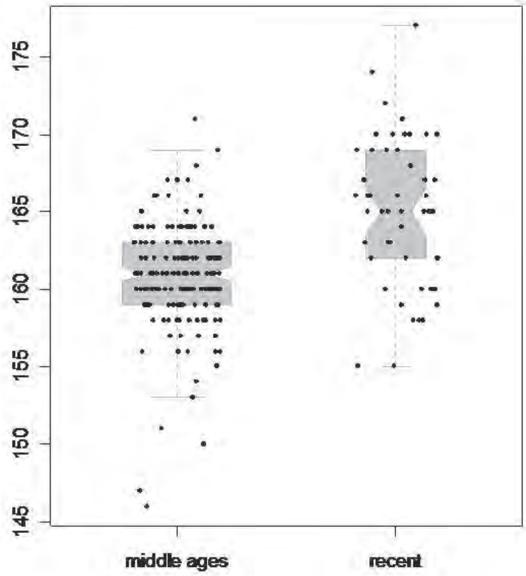
	Castle		Subcastle		Hinterland	
	n	%	n	%	n	%
very small	-	-	-	-	-	-
small	-	-	-	-	1	3,1
below medium	4	4,5	1	1,8	3	9,4
medium	11	12,4	13	23,2	5	15,6
above medium	25	28,1	18	32,1	8	25,0
tall	48	53,9	23	41,1	15	46,9
very tall	1	1,1	1	1,8	-	-

Table 9b. Representation of the stature categories according to social class (females).

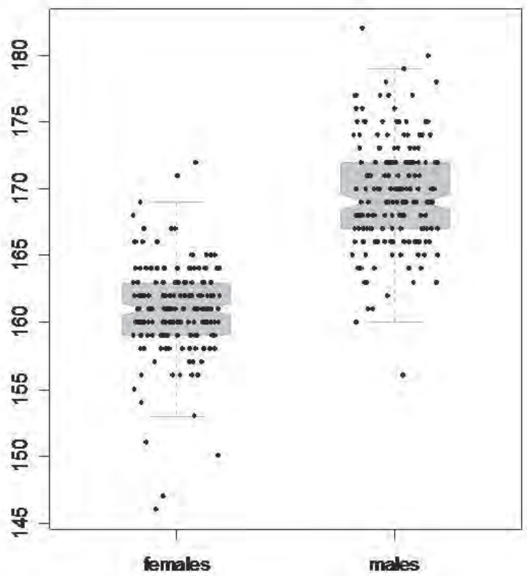
	Castle		Subcastle		Hinterland	
	n	%	n	%	n	%
very small	-	-	-	-	-	-
small	-	-	2	2,7	-	-
below medium	-	-	2	2,7	-	-
medium	-	-	3	4,0	-	-
above medium	5	8,2	10	13,3	6	15,0
tall	55	90,2	57	76,0	33	82,5
very tall	1	1,6	1	1,3	1	2,5



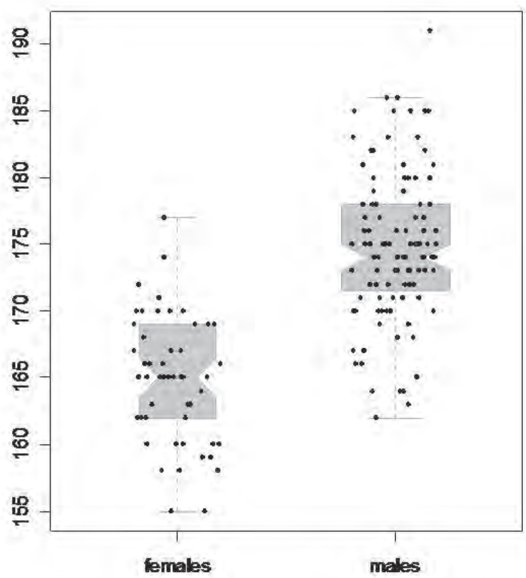
Graph 7. Boxplots of stature (in cm), males.



Graph 8. Boxplots of stature (in cm), females.



Graph 9. Boxplots of stature (in cm), Middle Age.



Graph 10. Boxplots of stature (in cm), recent.

Table 10a. Representation of height (stature) categories in the Great-Moravian and recent populations (males).

	Middle age		Recent	
	n	%	n	%
very small	-	-	-	-
small	1	0,6	-	-
below medium	8	4,5	2	1,9
medium	29	16,4	6	5,6
above medium	51	28,8	6	5,6
tall	86	48,6	71	66,4
very tall	2	1,1	22	20,6

Table 10b. Representation of stature categories in the Great-Moravian and recent populations (females).

	Middle age		Recent	
	n	%	n	%
very small	-	-	-	-
small	2	1,1	-	-
below medium	2	1,1	-	-
medium	3	1,7	2	3,8
above medium	21	11,9	3	5,7
tall	145	82,4	33	62,3
very tall	3	1,7	15	28,3

When comparing the Great-Moravian and recent populations, it may be said that tall stature dominate in both populations. The difference is in the representation of adjacent "height" categories. While in the Great-Moravian population we find greater representation on the left from the category of tall statures, i.e. in the above-average category; in the recent population there is a greater representation on the right, in the category of very tall individuals.

4. Conclusion

These results show that the studied Great-Moravian population was, according to the classical categorisation of Martin and Saller (1957) a population of tall and above-average stature, which is especially apparent in females. As mentioned before, this is a classification created using a population from the first half of the 20th century. Today, we have different ideas about "tall" stature thanks to the positive secular trend. The average stature of males in Great Moravia was approximately 170 cm, while females were approximately 161 cm tall. It must be stressed that these are average values, i.e. it does not mean that the population did not include individuals taller than 180 cm or on the other hand shorter than 160 cm. The minimum for males from the whole group from Great Moravia was 156.5 cm (H-P), the maximum 182.5 cm (C-M-II). For females, the minimum was 146.5 cm (S-M-K) and the maximum 171 cm (S-M-K). No statistically significant difference in stature was found among the various social classes, either in males or females. The fact that can be traced is that in the highest social classes, there was a trend towards greater percentage representation of individuals in the category "tall stature", especially among the female population. When comparing all three social classes, the population from below the castle included the least number of tall individuals, and this applied to both genders. This fact was again more marked in females than in males.

Compared to the recent population, the Great-Moravian population was statistically significantly shorter, and this applied to both genders.

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P. Velemínský/L. Poláček (Hrsg.), Studien zum Burgwall von Mikulčice VIII. Brno 2008, 93-120
Anthropological and epidemiological characterization of Great-Moravian population in connection with the social and economic structure

Craniometric Analysis of the Great Moravian Population from Mikulčice – X-ray film study

Jana Velemínská[1] – Petr Velemínský[2] – Lucie Bigoni[1] – Marek Jantač[2]

The study was focused on detailed craniometric analysis of lateral X-ray films of a highly-representative sample of 129 well-preserved skulls of Slavs from Mikulčice. Using special craniometric software, a total of 170 linear, angular, proportional and special dental chracteristics was evaluated. We focused on size and shape craniofacial sexual dimorphisms. Male skulls were significantly larger in all linear dimensions except for the height of the occipital bone. In the males an indentation between the nasal bones and os frontale, as well as more conspicuous anteriorotation of mandible was recorded. The females, on the other hand, had a more prominent proclination of both the dento-alveolar maxillar process and the medial upper incisors. The determined average metric data were compared with the norms of the recent population, which were developed specifically for the needs of bioachaeology. The skulls of recent population were characterized by two general morphological features: neurocranial globularity and retrusion of jaws. The length of the mandible is shortened, while the height of its ramus is extended. The overall height of the face, the intermandibular and interalveolar relationships has not changed from the Middle Ages to the present day. We also compared certain basic skull dimensions (e.g. length and height of the skull, the height of the whole face as well as the upper and lower face) with historical populations of the upper Palaeolithic, Neolithic, Eneolithic, Bronze, Middle and Modern Age. The relationship between recent, Early Middle Age and other historical populations that lived on the territory of our state was evaluated using cluster analysis. The results obtained are in concordance with both the morphological and the molecular genetic studies used for comparison.

Key words: Great Moravian population – craniometric analysis – X-ray film

1. Introduction

Despite the massive development of experimental and genetic techniques, craniometry remains an integral part of research into current and past populations. It is an important analytical method in the area of palaeoanthropology and forensic anthropology. It indirectly provides information which is also usefull for archaeology, history and other related sciences. It is commonly known that the size and shape of the skull are strongly controlled by genetic mechanisms (e.g. Manfredi et al. 1997; Johannsdottir et al. 2005). A study of skull morphology may thus answer questions pertaining to intra and inter-population variability.

The methodology of craniometry has undergone significant development from real measurement of skulls to 2D craniometric analysis of photographs or X-rays to classical or geometric morphometry of 3D skull models.

Classical craniometry is usually supplemented by 2D graphical analysis of lateral X-ray films or photographs. The metric evaluation of X-rays is still common, and indeed optimal for resolving many issues in the field of clinical anthropology.

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Analysis of lateral X-ray films is most frequently used in orthodontics or the study of congenital defects (Šmahel 1987). The importance of X-rays in skeletal anthropology lies not only in the documentation of pathological findings but also in the monitoring of mutual relations between endo- and ectocranial structures, their macro and micro-evolutionary changes in either the temporal and geographical horizon (Wescott/Jantz 2005).

Craniometric analysis is used for the detailed evaluation of variability and development of the craniofacial complex as a whole. It also facilitates the monitoring of intracranial relations between the individual structures (Keeling et al. 1989; Key/Jantz 1981, de la Rua 1992).

The method contributes towards the identification of growth patterns, the evaluation of mandibular rotation and the monitoring of saggital intermandibular relations. Many authors have monitored the mutual relationship between certain structures of the skull. Björk (1955) analysed the mechanism of growth of the base of the cranium during adolescence; Anderson and Popovich (1983) studied the relationship between the curvature of this important structure, the skull shape and the position of the mandible. As the maxilla and mandible are in contact with the base of the cranium, it can logically be presumed that the length and angle of the base affect the mutual relationship between the lower and upper jaw, thus also affecting occlusion. Understanding similar relationships and their mechanisms is highly significant in the field of evolutionary biology, for instance.

Vlček and Šmahel (1997, 1998) used metric evaluation of lateral X-ray films in research conducted on the remains of Czech monarchs. They compared the proportions of the skulls with norms valid for the present Czech population. They also determined certain selected proportions in upper Palaeolithic skulls from Dolní Věstonice (Vlček/Šmahel 2002) and in important personalities from the field of culture (e.g. Vlček et al. 2006). Macková (2004) created norms applicable in the craniometric analysis of photographs which were then used to verify the reliability of their measurement (Velemínská et al. 2003) and also for the study of macroevolutionary changes of skulls (Velemínská et al. 2005).

The variability of skull shapes is best characterised by methods of geometric morphometry. These 2D and 3D geometric morphometric methods are based on the analysis of using shape curves (e.g. Fourier's analysis), or of landmarks. Localisation of landmarks forms the basis for methods such as the FESA method (Richtsmeier/Cheverud 1986; Sameshima et al. 1996; Singh/Rivera-Robles/de Jesus-Vinas 2004), Bookstein and Procrustes transformation (Bookstein 1991) or the TPS method (Singh/McNamara/Lozanoff 1997; Dryden/Mardia 1998). The shape evaluation of skulls independently on their size, using methods of geometrical morphometry is our aim in a subsequent publication.

The goal of this study was the detailed craniometric analysis of X-ray films of a highly representative sample of well-preserved skulls of Slavs from Mikulčice. The main advantages of the methodology described in the text below include the measurement of classically inaccessible structures and the high precision of the measurement and estimation of morphological traits thanks to the enlargement of the digitized image, the alteration of brightness and contrast and the option of using various filters in the computer's memory.

We focused on sex-associated size and shape skull dimorphisms. Then we compared the linear, angular and special inter-maxillar and dental traits with the recent population. We also compared certain basic skull dimensions (e.g. length and height of the skull, the height of the whole face as well as the upper and lower face) with historical populations of the upper Palaeolithic, Neolithic, Eneolithic, Bronze, Middle and Modern Age.

2. Material

Craniometric analysis was performed on a sample of skulls from the Early Middle Ages from the Mikulčice power centre. A total of 129 adult skulls were analysed, of which 65 were male and 64 female. They came from burial areas near the first,

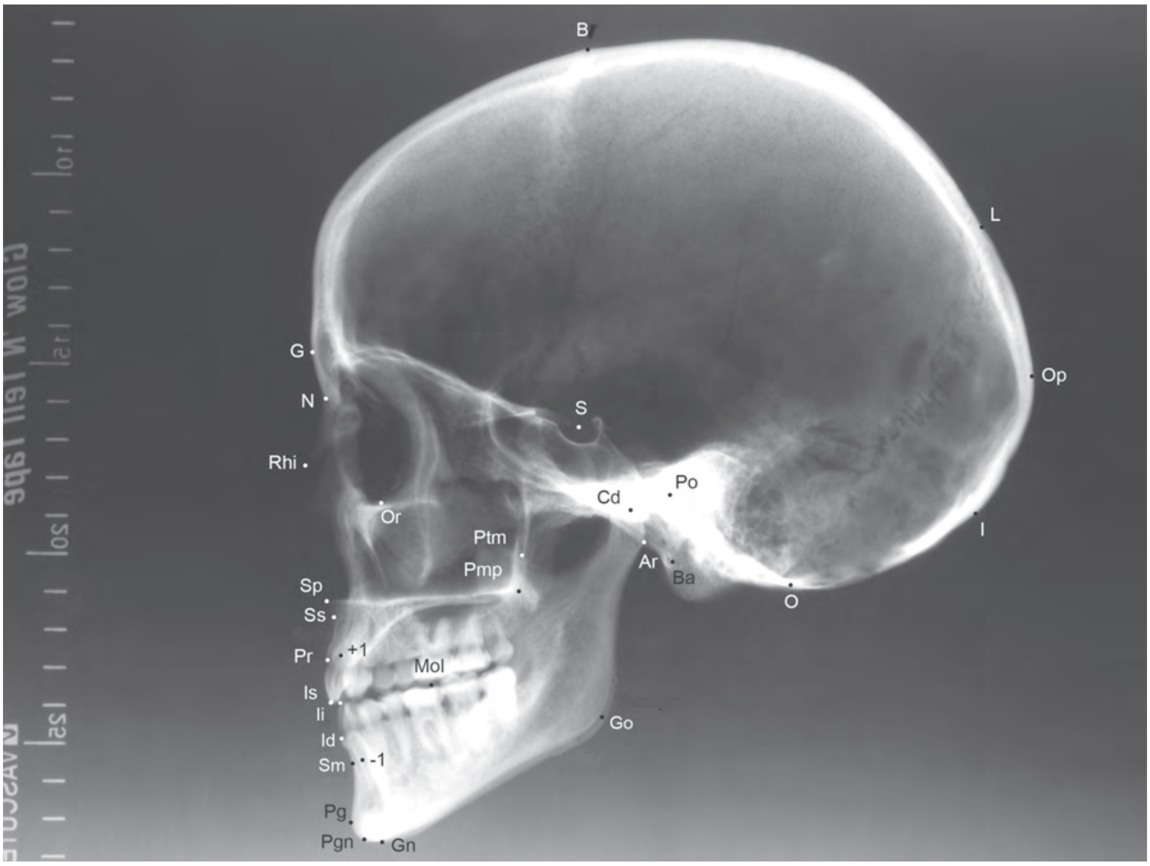


Fig. 1. Craniometric points (landmarks) used in this study: **Ar** (articulare) – intersection of inferior contour of the posterior cranial base and posterior contour of the ramus; **B** (bregma) – intersection of the coronal and sagittal sutures; **Ba** (basion) – most posteroinferior point on the clivus; **Cd** (condylion) – most superior point on the condylar head; **G** (glabella) – the most anterior point on the arcus superciliaris; **Gn** (gnathion) – the lowest point of the mandibular symphysis; **Go** (gonion) – point on the angle of the mandible determined by the axis of ML/RL angle; **I** (inion) – top of the protuberantia occipitalis externa; **Id** (infradentale) – point of the alveolar contact with the lower central incisor; **Ii** (incision inferius) – incisal tip of the lower central incisor; **Is** (incision superius) – incisal tip of the upper central incisor; **L** (lambda) – intersection of the sagittal and lambda sutures; **Mol** (molare) – tip of the posterior cuspid of the lower first molar; **N** (nasion) – the most anterior point on the frontonasal suture; **O** (opisthion) – point located at the midpoint of the posterior border of the foramen magnum; **Op** (opistocranion) point on the surface of the cranial vault farthest from the glabella point; **Or** (orbitale) the lowest point on the orbital margin; **Pg** (pogonion) – the most anterior point on the bony chin; **Pgn** (prognathion) – point on the mandibular symphysis farthest from Cd; **Pmp** (pterygomaxillare palatinum) – point of intersection of the palate plane and fissura pterygomaxillaris; **Po** (porion) the most superior point on the porus acusticus externus; **Pr** (prosthion) – point of alveolar contact with the upper central incisor**; Ptm** (pterygomaxillare) – most inferior point of the fossa pterygopalatina where fissura pterygomaxillaris begins; **Rhi** (rhinion) – the most anteroinferior point on the nasal bone; **S** (sella) – centre of sella turcica; **Sm** (supramentale) – the deepest point on the anterior contour of the mandibular symphysis**; Sp** (spinale) – tip of the anterior nasal spine; **Ss** (subspinale) – the deepest point of the subspinal concavity; **+1** – axis of the upper incisor; **-1** – axis of the lower incisor;

second, third, sixth and eleventh Mikulčice church and from the burial areas at Mikulčice-Kostelisko and Mikulčice-Klášteřisko. With the exception of two juveniles (one male and one female), all the individuals were adults. In the case of the males, we estimate that 18 individuals died in the adultus category, and 47 individuals were older than forty years. 31 females belonged to the adultus category, and 23 females probably reached maturity. The basic condition for selecting skeletal material from Mikulčice was a good state of preservation of the skulls with the lower jaw including intact dentition, so that articulation with the mandibular joint and occlusion of the upper and lower jaws was possible.

The lower jaw was fixed to the skull with the aid of adhesive gum, which was removed immediately after the images were checked, with no remnants or damage to the skulls.

The comparative recent sample entailed lateral X-ray films of 52 healthy males and 36 females from the archive of the Clinic of Plastic and Reconstructive Surgery, 3rd Faculty of Medicine, Charles University in Prague. Norms specially created for the needs of bioarchaeology were developed by Macková (2004).

Another goal of the study was to compare the skulls not only with recent but also with historical populations. We used the comparative data for the Upper Palaeolithic Age from Matiegka's (1934) and Vlček's (1997) publications; for the Neolithic Age from the publications of Černý/Velemínský (1998); for the Eneolithic and Bronze Age from the PhD thesis of Černý (1999). We also included other Great Moravian (Hanáková/Staňa/Stloukal 1986), Middle and Modern Age (Hanáková/Sekáčová/Stloukal 1984) burial grounds. The aforementioned authors conducted direct measurements of the skulls, and thus we could use only published dimensions, which were not distorted on the X-ray films, i.e. measured in the medial plane.

3. Method

The skulls were X-rayed using the COSMOS 2 skiagraphic apparatus at the Anthropological Department of the National Museum in Horní Počernice. They were scanned under standard conditions in lateral projection at a distance of 1 metre. The X-ray films were then digitized. The landmarks were localized using the SigmaScan program, Version 5. The craniometric analysis was based on a total of 30 landmarks that are schematically marked in Fig. 1. The caption of the figure contains exact definitions of all the used points. The following lines were used to mark the angular dimensions or the distance between the points and the planes: **NSL** – line passing through points N and S, **VL** – line perpendicular to line NSL at point S, **PL** – line passing through points Sp and Pmp, **OL** – occlusion line passing through the centre of the distance connecting the apices of the upper and lower incisors at the central occlusion and point Mol, **+1** – axis of the upper middle incisors, **-1** – axis of the lower middle incisors, **CL** – line passing through points Pg and Id, **ASL** – tangent to the alveolar process of the upper jaw passing through point Pr, **ML** – tangent of the body of the lower jaw passing through point Gn, **RL** – tangent of the ramus of the lower jaw passing through point Ar.

Duplicate contours may appear on the images, most often in the region of the angle and ramus of the mandible. In such cases, we used a point lying in the middle, between both sides. The most variable factor is the localisation of points on the contour concavities and convexities such as e.g. gonion, condylion, subspinale, supramentale and others.

The entered landmarks are the primary data for metric evaluation of the X-ray films using the application "Craniometrics", which was developed as a MS Excel application. It enables the single measurement of the required amount of selected metric variables of the neurocranium and facial skeleton on the calibrated images. These include linear dimensions (the distance between two points, the distance between a point and a straight line) and angular characteristics (angles determined by three points or two straight lines) that can be pre-defined according to specific needs. We thus programmed the required scale of traits, and by using one command we were able to measure numerous sets of digitalised lateral X-ray films. The output comprised the measured variables in a table editor which could be further manipulated and processed statistically.

Together with this variable component, which could also be used to measure, other parts of the skeleton or of photographs of a known scale, the program included special dental and mandibular dimensions (see below).

For the sake of clarity, we include the various types of designations of the dimensions used and the definitions of certain special dimensions. For example, the vertical distance from the point of the reference line (positional dimension) is denoted as Ar-VL; angles are denoted as N-S-Ar or as a fraction of two reference lines forming the given angle (ML/RL). This study is also based on certain proportional characteristics such as S-Go%N-Gn designating the dimension of S-Go as a percentage of the N-Gn dimension. The slope of the axis formed by the upper incisors in relation to the palatal plane is designated +1/PL; that formed by the lower incisors in relation to the body of the mandible is designated –1/ML. Overjet (Is-Ii) is defined as the distance between the cusps of the upper and lower incisors measured parallel with the occlusion plane; overbite (Is+Ii) is the distance between the cusps of the upper and lower incisors assessed perpendicular to the occlusion plane. Pr+Id is the difference between point Pr and Id after their perpendicular projection to the modified occlusion plane that passes through the centre of the distances of the upper and lower incisors and the peak of angle PL/ML (if Pr is posterior to Id, the value is negative). Ss+Sm is the difference between points Ss and Sm after their perpendicular projection to the mentioned modified occlusion plane (if Ss is posterior to Sm, the value is negative).

Within the Craniometrics software we selected a total of 107 characteristics (50 linear, 43 angular, three indexes and 11 special dental variables). The designations of the dimensions, average values, SD and their numbers are cited in the tables in the Result section of the study. They are always divided into three tables: dimensions of the neurocranium, linear dimensions of the splanchnocranium and dimensions characterising the shape of the facial skeleton.

We used the Statistica 6.0 software for statistical analysis, with the aid of which we calculated the basic statistical indicators, of which tables 1-9 include number of measurement (N), the mean, standard deviation (SD), t-value, degree of freedom (df) and level of significance (p) for the individual variables. We evaluated sexual dimorphism (Tables 1-3) and the comparison with a recent (Tables 4-9), or Neolithic population (Tables 10-13) with the aid of a two-sample t-test. We used analysis of variance – Scheffe' test – for comparison with the Eneolithic and Únětice populations (Tables 14-15). We included a total of 10 populations living in the region of the Czech Republic from an aspect of sexual dimorphism into a cluster analysis (Euclidean distance, complete linkage). The relationship between the populations (Graph 1, 2) was assessed on the basis of four size dimensions (M1, M17, M47, M48).

4. Results

4.1 Sexual dimorphism

Estimation of the skeleton's sex was conducted depending on the state of preservation of the pelvic bones. In individuals with a preserved pelvis, sex was determined with the aid of so-called primary sexual diagnosis (Brůžek/Velemínský 2006). In the case of the other skeletons, sex was determined on the basis of the morphology of the whole skeleton (e.g. Stloukal 1963, 1967; Stloukal/Hanáková 1985; Velemínský et al. 2005). The sample of 129 skulls included 65 male and 64 female skulls. We tested sexual dimorphism using a two-sample t-test, the results of which are detailed in Tables 1-3. The most significant differences are illustrated in colour (Fig. 2). Important, significantly larger dimensions of the males are highlighted in red and those of females in green. Dimensions with similar size are in black. Linear (size) distances mostly show significantly larger cranial dimensions in male individuals. The exceptions in the case of the facial skeleton are the heights of the upper (Sp-PL) and lower (Id-Sm) alveolar process and the height of the nasal bones (N-Rhi). These are structures frequently very poorly preserved (Rhi, Sb, Id regions). Another explanation may be the reduction of the alveolar processes associated with age-related changes of these structures.

In the neurocranial region there are no significant differences in the region of the occipital bone (L-Op, L-O, L-NO, Op-NO, I-NO). The average length dimensions encompassing the area of the face until the occipital region are longer in males than in females (e.g. G-L, G-Op, G-I).

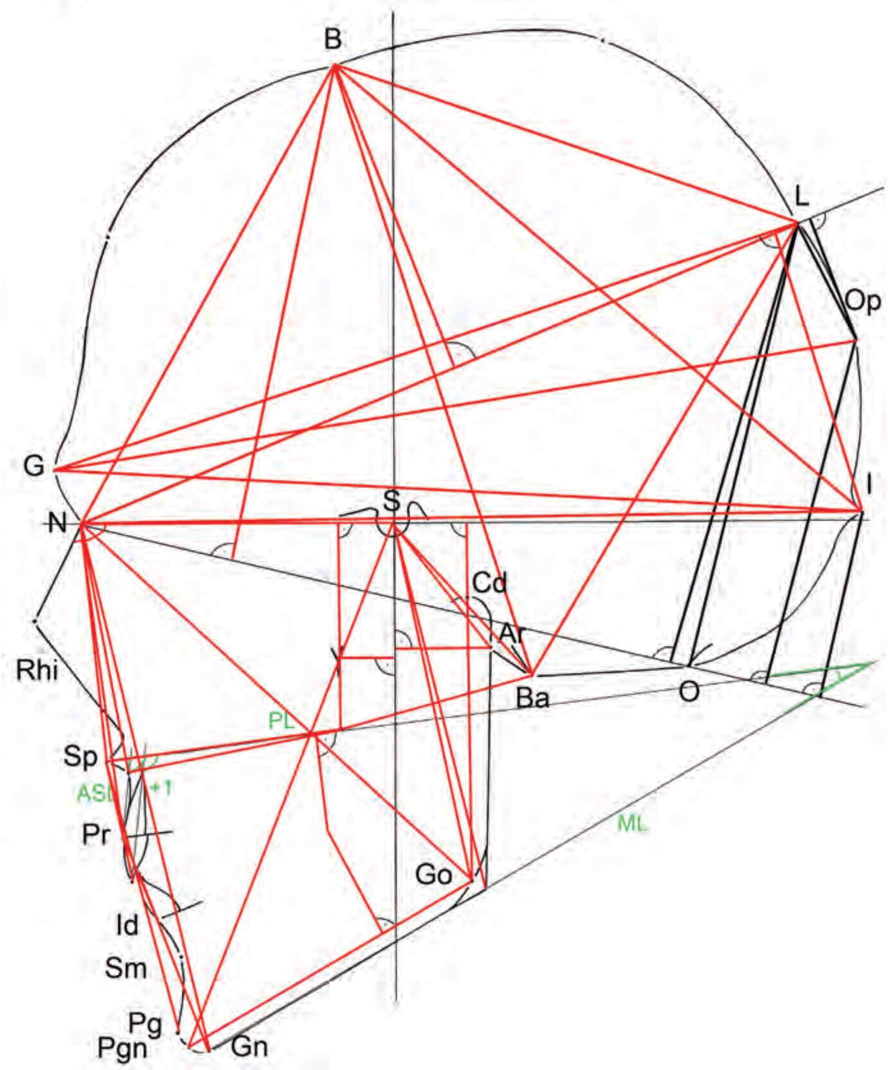


Fig. 2. Lateral craniogram with the most important sexual differences coloured (red – dimension significantly greater in males, green – dimension significantly greater in females, black – dimension without significant differences).

As for shape characteristics (angular dimensions), significant differences are – in contrast – less frequent. In males the indentation in the area of the nasal radix (S-N-Rhi) is more pronounced. The anteriorotation of their lower jaw is on average more pronounced by three degrees. In contrast, females have a more protruded upper alveolar process as well as upper incisors in relation to the plane of the palate (ASL/PL, +1/PL) and to the plane of mandible (ASL/ML). Significant differences in the characteristics of ML/NSL and S-Go%N-Gn show that the lower jaw of the male skulls assumes more significant anteriorotation compared to female skulls.

Similarly to most of the determined angular dimensions characterising the shape of the face and the braincase, the angle of the cranial base (N-S-Ba) does not show any sexual dimorphism. The N-I-L angle representing the prominence of the external protuberant occipital prominence is sharper (of greater prominence) in males. Females have a relatively more vaulted cranium (N-B-Ba, N-L-Ba). The sagittal inter-mandibular and dental relationships are the same in both sexes.

4.2 Comparison of male skulls from the Middle Ages and recent periods

We compared the male skulls from the Middle Ages and from recent periods using the two-sample t-test, the results of which are summarised in Tables 4-6. The most significant differences are highlighted in colour (Fig. 3). Significantly larger dimensions relating to males from recent periods

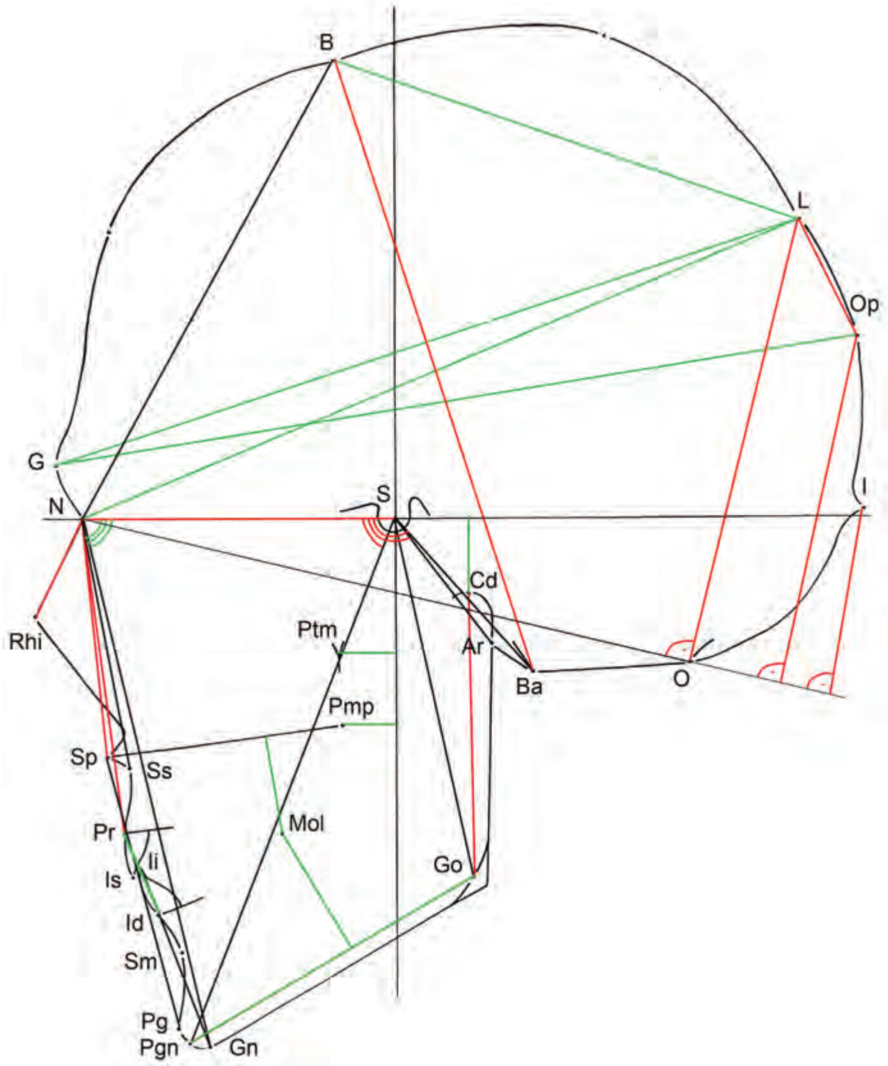


Fig. 3. Lateral craniogram with the most important differences between Medieval and recent skulls in males coloured (red – dimension significantly greater in recent skulls, green – dimension significantly greater in Early Medieval skulls, black – dimension without significant differences).

are highlighted in red, while those relating to males from Mikulčice are highlighted in green. Unchanged dimensions are in black.

The average cranium of males from Mikulčice is significantly longer (G-L, G-Op) and at the same time lower (Ba-B, L-NO, …). The values of the angular dimensions (e.g. N-B-O, N-L-O) correspond to this fact. It is interesting that in contrast the length of the anterior cranial base is longer in the recent population. The length of the posterior cranial base remains unchanged.

The overall height of the anterior (N-Gn) and posterior (S-Go) face does not differ in the two population samples studied. If we were to divide the anterior height of the face into an upper and lower region, males from Mikulčice have, on average, significantly lower height dimensions of the upper jaw (N-Rhi, N-Sp, N-Pr). The height dimensions of the lower face (Ii-Gn, Id-Gn, Sp-Pg) remain unchanged. The significantly reduced height dimensions of the maxilla in Slavs are also demonstrated by the index N-Sp %N-Gn. The depth of the maxilla (Ss-Pmp) is the same for both groups as a whole. A significant difference in favour of the recent group for the same dimension including the spina nasalis anterior (Sp-Pmp) may be due to the frequently incomplete preservation of the skeletal sample from Mikulčice. The ramus of the lower jaw is significantly shorter in the skulls from the Middle Ages, whilst the body of the lower jaw is significantly longer. The articular head (caput) of the lower jaw is at a significantly longer distance from the NS line (Cd-NSL). The molar point is more distant with respect to the

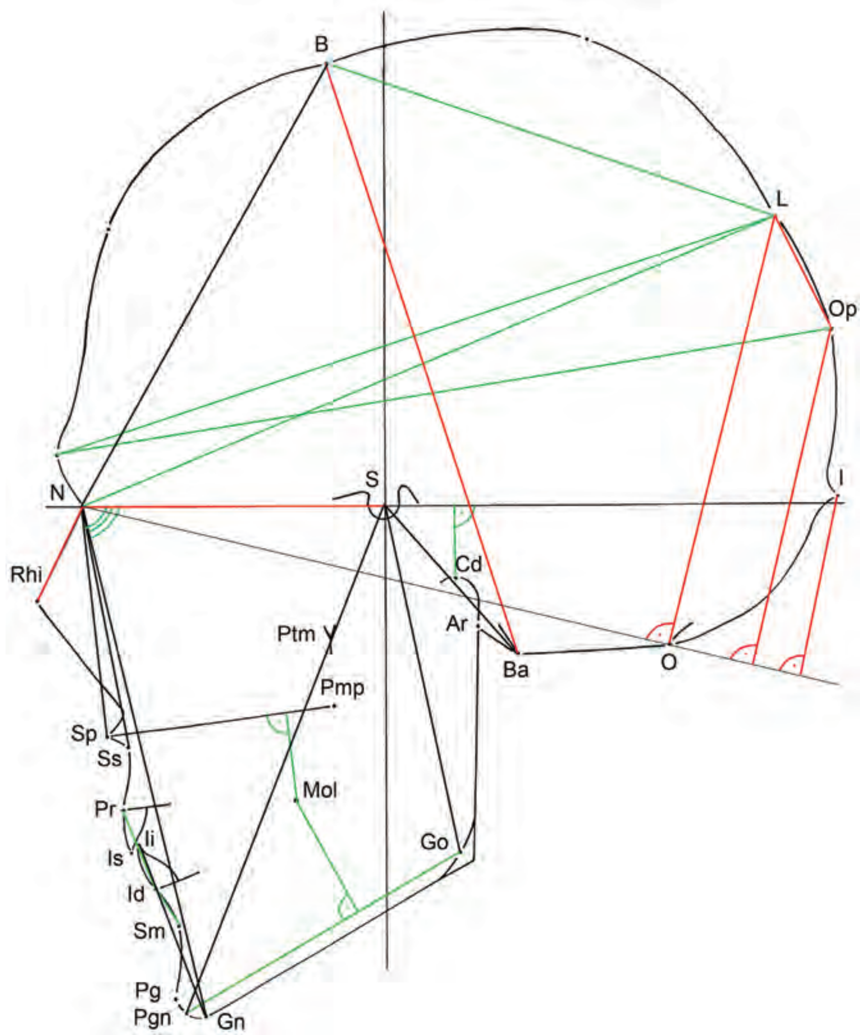


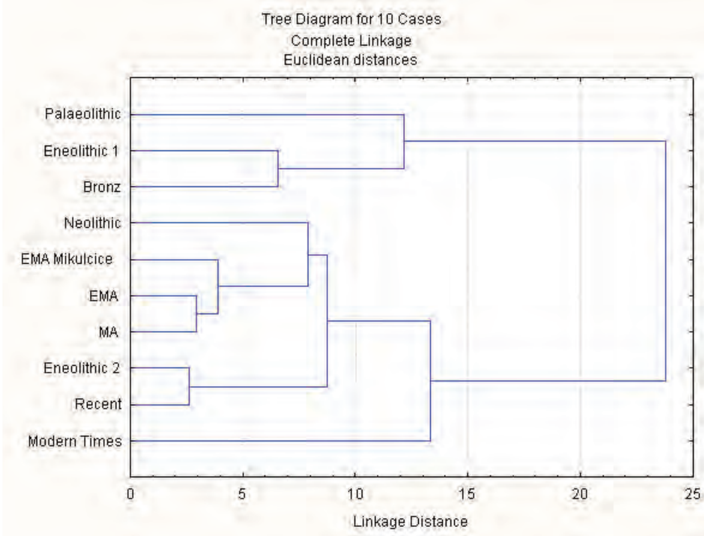
Fig. 4. Lateral craniogram with coloured the most important differences between Medieval and recent skulls in females (red – dimension significantly greater in recent skulls, green – dimension significantly greater in Early Medieval skulls, black – dimension without significant differences).

level of the palate plane (Mol-PL) as well as to the lower jaw plane (Mol-ML).

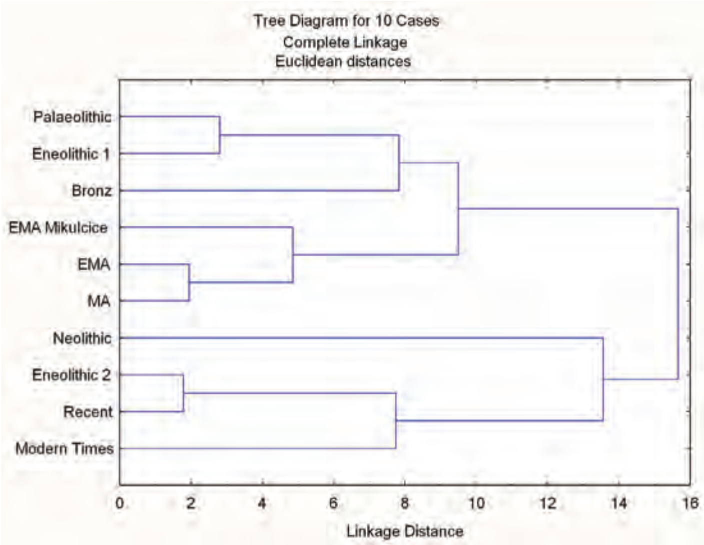
The angle of the cranial base in the Mikulčice Slavs is significantly smaller, as are the angles expressing the position of the mandibular joint or the antero-posterior position of the mandibular ramus (N-S-Cd, N-S-Ar). In contrast, the angular dimensions, which express the position of the skeletal profile in relation to the cranial base, are larger in the group from the Middle Ages, especially in the area of both alveolar processes and the whole lower jaw. Both jaws are thus in a position of slight protrusion. This subsequently leads to a non-significant accentuation of the convexity of the face, and the prominence of the chin is more emphasised. The angular dimensions characterising the shape of the lower jaw (ML/RL, CL/ML) or its position in relation to the other components of the skull (ML/NSL, RL/NSL, RL/PL, OL/ML) do not differ. The sagittal inter-mandibular and inter-alveolar relationships also remain stable in the two groups. Dimensions associated with rotation of the lower jaw (N-tGo-Gn, ML/NSL, S-Go%N-Gn) show similar average values in both groups. The first incisors do not show increased protrusion in relation to the corresponding structures (+1/NSL, -1/NSL, -1/ML). In contrast, +1/PL and ASL/PL dimensions show a retrusion of the upper incisors as well as the upper alveolar process in relation to the palate compared to the recent group.

4.3 Comparison of female skulls from the Middle Ages and recent periods

The skulls of females from the Middle Ages were compared with skulls from recent periods



Graph 1. Cluster analysis explaining the relationships between nine (pre)historical and one recent populations; Males (UP = Upper Palaeolithic, N=6; NEOL = Neolithic, N=15; CWC = Eneolithic Corded Ware culture, N=35; BBC = Eneolithic Bell Beaker culture, N=63; UC = Bronze Age Únětice culture, N=163; EMA = Early Middle Ages, N=175; MA = Middle Ages, N=394; MP = Early Modern period, N=68; REC = recent, N=52); Euclidean distances, complete linkage.



Graph 2. Cluster analysis explaining the relationships between nine (pre)historical and one recent populations; Females (UP = Upper Palaeolithic, N=5; NEOL = Neolithic, N=13; CWC = Eneolithic Corded Ware culture, N=20; BBC = Eneolithic Bell Beaker culture, N=37; UC = Bronze Age Únětice culture, N=97; EMA = Early Middle Ages, N=263; MA = Middle Ages, N=399, MP = Early Modern period, N=82; REC = recent, N=36); Euclidean distances, complete linkage.

using the two-sample t-test, the results of which are summarised in Tables 7-9. The most significant differences are highlighted in colour (Fig. 4). Significantly larger dimensions relating to females from recent periods are highlighted in red, while those relating to females from Mikulčice are highlighted in green. Unchanged dimensions are in black.

With a few exceptions, the differences in the cranial region are identical to those of the males; i.e. a longer and lower cranium in the Mikulčice females, a longer antrior cranial base in the recent population and an unchanged length of the posterior cranial base.

The overall height of the anterior (N-Gn) and posterior (S-Go) face does not differ in the two population samples studied and neither do most of the partial height dimensions of the anterior face. The significantly shorter height of the nasal bones may be due to the poorer preservation of the skulls from Mikulčice, compared to the evidence value of skull X-ray films of the recent population. In contrast, the greater height of the incisors on Pr-Id occlusion in Great Moravian females was probably due to incomplete occlusion (Is+Ii negative average values). The slightly reduced Sp-N dimension in combination with a slightly extended height of the face of Slav female led to a significantly lower N-Sp%N-Gn index. The depth of the maxilla in the groups of females is the same (Ss-Pmp). The significant difference in favour of the recent population for this same dimension including the Spina nasalis anterior (Sp-Pmp) could be due to the frequent incomplete preservation of the skeletal sample from Mikulčice.

The ramus of the lower jaw is non-significantly shorter in the skulls from the Middle Ages, whilst the body of the lower jaw is significantly longer. The articular head (caput) of the lower jaw is at a significantly longer distance from the NS line (Cd-NSL). The molar point is more distant with respect to the level of the plane (Mol-PL) as well as the plane of mandible (Mol-ML) in the recent population.

In the case of female skulls, the angle of the cranial base as well as the angles expressing the position of the mandibular joint or the antero-posterior position of the mandibular ramus (N-S-Cd, N-S-Ar) remain unchanged from the Middle Ages until today. The angular dimensions expressing the position of the skeletal profile in relation to the cranial base are significantly greater (S-N-Rhi, S-N-Ss, S-N-Pr, S-N-Id, S-N-Sm, S-N-Pg, S-N-Gn) in the population from the Middle Ages, with the exception of the S-N-Sp angle (probably affected by the preservation of the Spina nasalis anterior). Both jaws are thus in mild protrusion, which leads to a significant increasing of the convexity of the face.

The dental angular dimensions expressing the inclination of the incisors in relation to other structures of the female skulls remain unchanged over the ages, as do the inter-alveolar and inter-mandibular relations.

4.4 Comparison of skulls from the Early Middle Ages with those from Prehistoric and historical populations.

In this chapter, we attempted to compare data relating to populations from the Early Middle Ages with that from Prehistoric and historic populations, taking into consideration data accessibility and measurement techniques.

In our comparison of the Slavs from Mikulčice with the Neolithic or more recent populations, we used the dimensions (G-Op, B-Ba, N-Gn, N-Pr). The exact figures are detailed in Tables 10-13. It must be emphasised that the results may be affected by the poor preservation of Neolithic skulls and also by the low number of measurements cited in the appropriate tables (Černý/Velemínský 1998). Compared to Neolithic skulls, those from Mikulčice have a significantly greater facial height. The height of the skulls themselves, though, is shorter (significantly so only in the case of males). As to the length of the cranium, there are no differences between the two populations.

Using analysis of variance, we compared the size of skull dimensions of Mikulčice, Eneolithic (Bell Beaker Culture, Corded Ware Culture), Bronze Age (Unětice Culture) and recent skulls (Tables 14-15) separately for each of the following dimensions G-Op, B-Ba, N-Gn, N-Pr, N-Sp, Id-Gn). The length of the cranium of Slavs from Mikulčice differs most from the population with a culture of Bell Beaker Culture (not significant in female) and the recent population, both of which have on average the shortest cranium. The Eneolithic populations mutually differ significantly only in the length of their skull, which is longer in the Corded Ware Culture population. On average and in comparison with all the others, this population is most dolicho-cephalic (193 cm in males, 184 in females). From the aspect of skull length, the Eneolithic Bell Beaker Culture population most resembles the recent population.

As to the height of the cranium, Slavs have the lowest among all the studied populations. The skulls of male from Mikulčice differ significantly only from the Únětice Culture. Female skulls differ from all those of the studied populations with the exception of the Eneolithic Corded Ware Culture population.

As to the facial skeleton, female from Mikulčice differ only in the height of the lower face, which is significantly shorter only compared to the Únětice

Culture. Compared to this culture, the males, moreover, have a significantly shorter upper face.

We included a total of 10 samples of skulls from various periods to the construction of comparison diagrams (Graph 1, 2). Dendrograms were calculated separately for male and female skulls. Apart from the aforementioned data of Slavs from Mikulčice, recent, Neolithic, Eneolithic and Bronze Age populations, we also used data from Upper Palaeolithic skulls published by Matiegka (1934) and Vlček (1997). These included male skulls P3, P9, DV13, DV14, DV16, Pavlov I and female skulls P4, P10, DV3, DV15, Brno III. We also included in the analysis the average dimensions of skulls from the Early Middle Ages from Rajhrad (Hanáková/Staňa/Stloukal 1986), skulls from the Middle Ages and modern period from Ducové (Hanáková/Sekáčová/Stloukal 1984). The historical populations were clustered on the basis of their G-Op, B-Ba, N-Gn, N-Pr dimensions. On the dendrograms it is possible to follow congruently three main branches. The first cluster includes all the three burial grounds from the Middle Ages, with the Great Moravian burial ground in Rajhrad and the burial ground from the Middle Ages in Ducové showing the closest resemblance. The other branch is represented by Palaeolithic and Eneolithic skulls (Corded Ware Culture) and Bronze Age skulls (Únětice Culture). The third and last cluster conveys the similarities between recent, Modern Age and Eneolithic (Bell Beaker Culture) populations.

5. Discussion and conclusions

The main goal of this study was to monitor the variability of the Mikulčice skulls from the Early Middle Ages and to look for evolutionary changes in relation to historical and recent populations on the territory of the Czech Republic. Our underlying premise was the fact that the skull, a dynamic structure, changes during phylogenesis and ontogenesis. The size, shape and position of the individual skull components affect each other to a certain extent. Deviation of one component may lead to a series of changes to both neighbouring and more distant structures which enable these to adapt to primary stimuli. These mutual relations are determined by adaptation mechanisms in the skull (Šmahel/Škvařilová 1988).

If we focus on the most distinctive evolutionary changes of the skull approximately in the past 26.000 years, several significant differences are observed with respect to the present day. The Upper Palaeolithic skulls are relatively longer and narrower. Anteriorotation of the face produces a strong protrusion of the upper and lower jaw. The eye sockets and piriform aperture are wider. The crania of anatomically modern humans are characterised by two general structural features: facial retrusion and neurocranial globularity. The facial skeleton of recent skulls is narrower, including eye socket and piriform aperture (Svoboda 2006; Velemínská et al. 2005).

Among the main factors that contribute to changes in the shape of skulls from an evolutionary aspect, we include climatic changes (Beals/Smith/Dood 1983), a sedentary lifestyle associated with changes in food habits, improvement of health (Angel 1982), urbanism and others. It has been described that individuals with rounded (globular) types of skulls are more adaptable to new social situations and social stress. There is an unsubstantiated relation between brachycephaly and greater resistance of humans. Reduction in the length of the cranium is usually associated with a reduction of massetter muscles and the retrusion of both jaws (Velemínská et al. 2008).

The questions regarding the origin of the population of Bohemia and Moravia in the Neolithic period are being answered mainly by molecular genetics. Based on the results of MSY as well as mtDNA analysis, it is presumed that 20-25% of the current European population originates from Neolithic farmers (e.g. Semino et al. 2000). According to Kračmarová's results (2005), more than 4/5 of the population can trace their origin to the colonisation of our lands during the Early or Late Palaeolithic Age.

The study of skull morphology has also brought forth data consistent with the conclusions of molecular genetic analysis. Chochol/Blajerová/

Hanáková (1960) and Chochol (1964) states that the Neolithic-Eneolithic autochtonic formation in Bohemia embodies the traditions of the Mesolithic substrate, enriched and transformed by the invasion of farmers of the Mediterranoid anthropological type. Two invasion waves may be recognised during the Eneolithic period. In their view, the first is represented by people of the Corded Ware Culture, physically similar to the local population (hyper-dolichocephalic skull). The second invasion is represented by people of the Bell Beaker Culture (brachycephalic skull). The Únětice culture then postulates a strengthening of the cromanoid influence. If we compare these 40-year-old results with the dendrograms in Graph 1 and 2, the results of our cluster analysis are not inconsistent. On average, the Palaeolithic skulls (according to the parameters used) resemble most the Eneolithic (Corded Ware Culture) skulls and the skulls from Únětice. Neither Neolithic nor Eneolithic (Bell Beaker Culture) skulls, which could represent the newly arrived population in our lands, have a closer relationship with the others.

The missing link between the compared populations is found between the Únětice Culture and the Early Middle Ages. Fragmentation, low incidence of findings from the Latene period and the period of population migration are so great that we did not find any suitable published comparative group of craniometric data.

Comparative data relating to the Middle Ages, on the other hand, are plentiful. Preservation of Great Moravian burial grounds, for example, is very good. Proof of this are the 129 complete skulls in our study which could be subjected to detailed craniometric analysis. Slavic burial grounds from early settlements and the Middle Ages were investigated by Blajerová (1974, 1975), who also conducted a comparison of the populations from the Early Middle Ages until the Modern Age in Bohemia (Blajerová 1980). In this work she describes the gradual shortening and widening of the cranium, with the height of the skull and face remaining unchanged. In our results we have also noted a shortening of the cranium, in the Slavs from Mikulčice compared to the recent population, but the cranium also increased in height among both sexes. The overall height of the face has remained unchanged, in concordance with the results of Blajerová (1980). Neither has the height ratio of the anterior and posterior face (S-Go%N-Gn) changed, despite the change in the relationship between the upper and lower height of the face (N-Sp%N-Gn). This supported the findings of Manfredi et al. (1997) that the vertical parameters have a higher genetic control than the horizontal ones. Heritability, according to them, seems to have more influence on anterior vertical parameters than posterior ones.

Hanáková/Sekáčová/Stloukal (1984) described the burial ground in Ducové in Slovakia, where tombs from the Great Moravian period through the Middle Ages to the modern period were uncovered. Significant brachy-cephalization has been noted here, along with a widening of the face and a decline of the fronto-mandibular index in males. In the Great Moravian burial grounds in Rajhrad the average metric skull indicators that we were able to compare with ours (M1, 17, 47, 48, 69) were very similar (Hanáková/Staňa/Stloukal 1986). We included the data of Hanáková/Sekáčová/Stloukal (1984) and Hanáková/Staňa/Stloukal (1986) in our cluster analysis. Both burial grounds, Great Moravian and other Medieval, became closely associated in the case of male and female skulls, forming a common branch in our dendrogram. Dohnalíková//Dušek/Novotný (1997) used cluster analysis to study the mutual relationship between several Slavic burial grounds. Chronological and geographical differences between populations were described on the basis of neuro-cranial linear dimensions.

As expected, in the Slavs from Mikulčice we found significant sexual dimorphism of linear dimensions with the exception of the vertical dimensions of the occipital bone. Conversely, sexual dimorphism in the shape of skulls characterised by angular dimensions and proportions was very rare. Males have more prominent nasal bones in relation to the anterior cranial base. Females show a typically more significant proclination of the upper alveolar processes and upper incisors.

Detailed craniometric comparison with the recent population was conducted separately for both sexes. For both of them equally, the most typical evolutionary changes were the development of neuro-cranial globularity, decreased facial convexity and stable height of the face. We observed all these micro-evolutionary changes taking place over a period of roughly 1000 years, also in comparison with Upper Palaeolithic skulls. Our results correspond to the micro-evolutionary secular changes described by Jantz/Meadows Jantz (2000) and Wescott/Jantz (2005). This process assumes increasingly stronger expression among the Upper Palaeolithic and recent reference samples which were the subject of our previous study (Velemínská et al. 2008).

The lower jaw changes its basic dimensions from the Early Middle Ages until today. The length of its body is shortened, while the height of the mandibular ramus is extended (not significantly in females). In male skulls, height dimensions of the anterior and posterior face have extended over the ages. The angle of the cranial base has increased. The lower jaw is in retrusion, compared to the Middle Ages. Recent metric data from skulls included in the cluster analysis correlated most with the Eneolithic culture (Bell Beaker Culture) and also with Neolithic skulls in females. All the aforementioned groups had a short cranium in common.

The selected method of evaluating X-ray skull images provided data complementing classical craniometry. Structures inside the skull were evaluated (dimensions related to the Sella craniometric point), and inter-mandibular and inter-alveolar relations were also studied. Analysis of lateral X-ray images loaned by the Clinic of Plastic Surgery facilitated a detailed comparison and thus the monitoring of micro-evolutionary trends until modern times. On the other hand, comparison with historical populations was limited due to different methods of measurement or the preservation of the skeletal material. We plan to conduct a detailed study of the variability of skull shapes in the next stage of our research into the Great Moravian population using 2D and 3D methods of geometric morphometrics.

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Table 1. Sexual dimorphism of facial linear dimensions at the Mikulčice's population.

	N		Mean		SD				
Dimension	Male	Female	Male	Female	Male	Female	t-value	df	p
N-Rhi	55	52	18.356	17.452	3.180	3.489	1.402	105	0.164
N-Sp	62	61	50.588	48.430	3.367	3.248	3.618	121	0.000
N-Ss	64	60	55.480	52.657	3.686	3.340	4.460	122	0.000
N-Pr	63	62	67.364	64.681	4.244	4.717	3.344	123	0.001
N-Gn	65	63	119.678	112.646	7.745	7.491	5.218	126	0.000
N-Go	64	62	116.461	108.280	7.628	5.915	6.713	124	0.000
Sp-Is	36	35	28.699	26.947	2.468	3.084	2.646	69	0.010
Pr-Id	62	62	21.485	20.041	3.303	2.603	2.703	122	0.008
Ii-Gn	52	51	42.444	39.302	3.411	3.460	4.640	101	0.000
Id-Gn	64	63	32.154	29.629	3.198	3.198	4.448	125	0.000
Id-Sm	64	64	8.422	8.153	2.383	1.946	0.699	126	0.486
Sp-Pg	62	61	61.551	57.139	5.462	6.540	4.063	121	0.000
Sp-Pmp	61	61	49.925	47.424	2.924	2.930	4.719	120	0.000
Ss-Pmp	63	60	48.287	45.952	2.817	2.557	4.805	121	0.000
Pmp-Ba	63	59	44.704	42.623	3.089	3.409	3.537	120	0.001
S-Go	56	54	82.506	74.117	7.182	5.796	6.726	108	0.000
S-tGo	56	55	86.212	77.503	7.325	5.958	6.865	109	0.000
S-Pgn	57	56	126.983	118.456	6.673	6.393	6.934	111	0.000
Cd-Go	64	61	58.959	53.858	6.154	4.710	5.186	123	0.000
Pgn-Go	64	62	75.542	72.032	4.825	4.200	4.349	124	0.000
S-Ar	57	55	36.379	32.937	2.947	5.217	4.319	110	0.000
Pmp-NSL	58	57	45.050	42.063	3.455	3.897	4.353	113	0.000
Cd-NSL	60	59	22.415	19.272	4.422	4.508	3.839	117	0.000
Pr-PL	61	59	17.352	16.204	4.454	2.749	1.691	118	0.093
Mol-PL	51	48	25.649	23.297	2.891	3.355	3.743	97	0.000
Mol-ML	51	48	31.596	29.283	3.382	3.116	3.533	97	0.001
Pmp-VL	57	56	14.976	14.025	3.678	2.848	1.535	111	0.128
Ptm-VL	56	49	15.453	14.033	3.273	2.397	2.505	103	0.014
Ar-VL	57	55	20.256	18.102	3.644	2.953	3.430	110	0.001

Table 2. Sexual dimorphism of shape and dental characteristics of the face at the Mikulčice's population.

	N		Mean		SD				
Dimension	Male	Female	Male	Female	Male	Female	t-value	df	p
N-S-Ba	55	54	129.330	130.494	5.115	4.618	-1.246	107	0.215
N-S-Cd	56	55	125.691	127.160	7.034	7.019	-1.101	109	0.273
N-S-Ar	56	55	123.877	123.829	5.506	5.554	0.046	109	0.963
N-S-Go	55	54	100.981	101.983	4.713	4.217	-1.169	107	0.245
N-S-Pgn	57	56	66.422	66.593	3.968	3.842	-0.233	111	0.816
S-N-Rhi	52	51	115.705	111.534	7.470	8.153	2.708	101	0.008
S-N-Sp	55	54	85.722	85.495	4.006	4.389	0.281	107	0.779
S-N-Ss	56	53	83.753	83.541	3.507	3.596	0.310	107	0.757

	N		Mean		SD				
Dimension	Male	Female	Male	Female	Male	Female	t-value	df	p
S-N-Pr	55	54	85.673	85.966	3.587	3.383	-0.439	107	0.661
S-N-Id	56	56	82.291	82.336	3.396	3.238	-0.072	110	0.942
S-N-Sm	57	56	80.600	80.399	3.302	3.202	0.328	111	0.743
S-N-Pg	57	56	82.369	81.704	3.590	3.125	1.049	111	0.297
S-N-Gn	57	55	79.370	78.457	3.446	3.161	1.459	110	0.147
PL/NSL	54	54	5.978	6.973	3.376	3.512	-1.501	106	0.136
ML/NSL	56	54	27.701	30.349	5.964	5.684	-2.382	108	0.019
ML/RL	64	61	120.626	122.082	7.626	5.857	-1.193	123	0.235
CL/ML	63	62	69.693	70.392	5.452	5.208	-0.732	123	0.466
RL/NSL	56	59	87.297	85.724	6.058	9.611	1.044	113	0.299
RL/PL	60	61	98.454	97.712	5.845	12.422	0.419	119	0.676
PL/ML	60	60	21.931	24.308	5.900	5.267	-2.328	118	0.022
ASL/PL	59	56	103.598	107.176	6.552	6.806	-2.872	113	0.005
ASL/NSL	56	58	98.828	101.015	8.372	7.695	-1.453	112	0.149
S-Ar-tGo	57	55	142.853	145.312	8.243	7.623	-1.637	110	0.104
OL/NSL	25	28	12.024	15.004	5.300	6.541	-1.808	51	0.076
Ar-tGo-N	64	60	48.489	48.613	4.710	4.291	-0.153	122	0.879
N-tGo-Gn	64	60	72.138	73.317	4.991	5.051	-1.306	122	0.194
N-Ar/OL	28	32	30.823	31.505	4.756	4.366	-0.579	58	0.565
N-Ss-Pg	64	60	177.234	176.549	5.642	5.821	0.665	122	0.507
Ss-N-Sm	64	60	3.130	3.023	2.326	2.538	0.245	122	0.807
Pr-N-Id	62	62	3.466	3.545	1.928	1.971	-0.228	122	0.820
S-Go%N-Gn	56	53	0.690	0.659	0.047	0.044	3.435	107	0.001
S-tGo%N-Gn	56	54	0.721	0.690	0.050	0.047	3.298	108	0.001
N-Sp%N-Gn	63	60	0.430	0.431	0.057	0.024	-0.198	121	0.843
+1/PL	38	33	104.779	108.810	7.593	6.930	-2.323	69	0.023
-1/ML	52	50	95.762	94.514	6.900	7.080	0.901	100	0.370
+1/-1	35	34	134.759	131.243	10.915	10.608	1.356	67	0.179
+1/NSL	34	32	99.083	101.350	8.578	8.051	-1.105	64	0.273
-1/NSL	46	43	55.793	53.474	7.507	6.949	1.509	87	0.135
Is-Ii	29	35	2.361	2.573	2.072	2.384	-0.375	62	0.709
Is+Ii	29	34	-0.249	-0.216	1.883	1.869	-0.068	61	0.946
Ss+Sm	28	31	0.950	0.330	2.294	2.684	0.949	57	0.347
Pr+Id	27	32	2.849	2.485	2.410	2.680	0.545	57	0.588
Ss+Sm(modif.OL)	33	34	-0.588	-0.890	3.351	3.434	0.364	65	0.717
Pr+Id(modif.OL)	32	35	1.845	2.014	3.090	2.894	-0.230	65	0.818

Table 3. Sexual dimorphism of linear and shape characteristics of the neurocranium the Mikulčice's population.

	N		Mean		SD				
Dimension	Male	Female	Male	Female	Male	Female	t-value	df	p
N-S	57	56	68.267	64.793	3.221	3.327	5.640	111	0.000
S-Ba	56	54	45.007	41.144	3.542	2.639	6.468	108	0.000
G-Op	65	62	187.536	179.793	7.840	6.407	6.077	125	0.000
Ba-B	64	58	136.537	130.948	6.477	5.337	5.171	120	0.000
N-B	65	63	112.638	108.841	5.138	4.237	4.554	126	0.000
B-L	65	63	118.793	115.839	6.850	6.088	2.576	126	0.011
L-Op	65	62	28.652	27.361	7.238	7.315	1.000	125	0.319
L-Ba	64	58	116.469	112.713	5.896	5.203	3.715	120	0.000
N-L	65	63	178.718	172.741	7.100	6.154	5.082	126	0.000
N-I	65	60	174.417	166.204	8.318	6.785	6.020	123	0.000
G-L	65	63	181.014	174.049	7.405	6.049	5.817	126	0.000
G-I	65	60	180.507	171.036	8.666	6.961	6.702	123	0.000
B-I	65	60	155.336	149.278	6.363	6.658	5.200	123	0.000
L-O	65	60	96.537	95.027	5.227	5.338	1.597	123	0.113
B-NO	65	58	149.287	143.935	6.014	5.828	4.999	121	0.000
L-NO	65	60	95.392	93.587	5.394	5.580	1.839	123	0.068
Op-NO	65	59	72.678	71.362	5.717	6.878	1.163	122	0.247
I-NO	65	58	35.904	35.446	5.797	5.441	0.450	121	0.653
B-NL	65	63	73.330	71.654	4.767	4.257	2.095	126	0.038
Op-NL	64	62	28.803	27.243	6.874	7.340	1.232	124	0.220
I-NL	65	60	60.717	57.646	5.988	6.285	2.797	123	0.006
N-B-O	65	61	61.091	59.488	2.848	2.751	3.211	124	0.002
N-L-O	65	60	49.421	47.823	2.528	2.897	3.293	123	0.001
N-Op-O	65	59	43.340	41.969	2.609	2.768	2.838	122	0.005
N-I-O	65	58	35.041	35.034	3.421	4.067	0.011	121	0.991
N-B-L	65	63	101.149	100.519	3.552	3.372	1.028	126	0.306
N-Op-L	65	62	75.830	76.821	3.246	3.376	-1.688	125	0.094
N-I-L	65	60	83.485	85.867	4.113	3.867	-3.329	123	0.001
N-S-B	57	55	84.354	83.938	3.133	3.841	0.629	110	0.531
N-S-L	57	55	151.431	151.118	3.677	4.984	0.378	110	0.706
N-S-I	57	53	175.063	175.361	3.791	3.228	-0.442	108	0.660
N-S-Op	57	54	165.467	165.106	3.816	4.897	0.434	109	0.665
N-S-O	57	54	152.497	152.182	4.551	4.614	0.362	109	0.718
Ba-O/NSL	56	51	5.008	4.898	3.227	3.357	0.173	105	0.863

Table 4. Craniofacial comparison between Early Medieval and recent males (linear dimensions of the face).

	Mean		N		SD				
Dimension	Mikulčice	Recent	Mik.	Rec.	Mikulčice	Recent	t-value	df	p
N-Rhi	18.356	23.078	55	52	3.180	3.634	-7.162	105	0.000
N-Sp	50.588	52.936	62	52	3.367	3.395	-3.694	112	0.000
N-Ss	55.480	56.128	64	52	3.686	3.347	-0.981	114	0.329
N-Pr	67.364	69.855	63	52	4.244	4.030	-3.204	113	0.002
N-Gn	119.678	120.281	65	52	7.745	6.769	-0.443	115	0.659
N-Go	116.461	117.681	64	52	7.628	4.786	-1.004	114	0.318
Sp-Is	28.699	28.808	36	52	2.468	3.178	-0.174	86	0.863
Pr-Id	21.485	19.485	62	52	3.303	2.049	3.795	112	0.000
Ii-Gn	42.444	42.485	52	52	3.411	3.285	-0.062	102	0.951
Id-Gn	32.154	32.193	64	52	3.198	2.911	-0.069	114	0.945
Id-Sm	8.422	8.401	64	52	2.383	2.463	0.047	114	0.963
Sp-Pg	61.551	62.351	62	52	5.462	6.018	-0.744	112	0.459
Sp-Pmp	49.925	53.377	61	52	2.924	3.192	-5.995	111	0.000
Ss-Pmp	48.287	48.935	63	52	2.817	2.957	-1.201	113	0.232
Pmp-Ba	44.704	44.102	63	52	3.089	2.924	1.066	113	0.289
S-Go	82.506	81.999	56	52	7.182	5.233	0.417	106	0.678
S-Pgn	126.983	125.826	57	52	6.673	5.974	0.950	107	0.344
Cd-Go	58.959	61.619	64	52	6.154	4.158	-2.661	114	0.009
Pgn-Go	75.542	73.311	64	52	4.825	3.839	2.708	114	0.008
S-Ar	36.379	35.819	57	52	2.947	3.332	0.932	107	0.353
Pmp-NSL	45.050	45.431	58	52	3.455	3.007	-0.612	108	0.542
Cd-NSL	22.415	18.688	60	52	4.422	3.922	4.685	110	0.000
Pr-PL	17.352	16.981	61	52	4.454	2.904	0.514	111	0.608
Mol-PL	25.649	24.583	51	52	2.891	2.237	2.095	101	0.039
Mol-ML	31.596	30.259	51	52	3.382	2.656	2.234	101	0.028
Pmp-VL	14.976	12.479	57	52	3.678	2.835	3.942	107	0.000
Ptm-VL	15.453	12.798	56	52	3.273	2.418	4.764	106	0.000
Ar-VL	20.256	20.978	57	52	3.644	2.904	-1.136	107	0.258

Table 5. Craniofacial comparison between Early Medieval and recent males (shape and dental characteristics of the face).

	Mean		N		SD				
Dimension	Mikulčice	Recent	Mik.	Recent	Mikulčice	Recent	t-value	df	p
N-S-Ba	129.330	131.627	55	52	5.115	5.516	-2.235	105	0.028
N-S-Cd	125.691	128.847	56	52	7.034	8.402	-2.122	106	0.036
N-S-Ar	123.877	126.128	56	52	5.506	5.123	-2.195	106	0.030
N-S-Go	100.981	101.709	55	52	4.713	4.199	-0.841	105	0.402
N-S-Pgn	66.422	68.198	57	52	3.968	4.102	-2.297	107	0.024
S-N-Rhi	115.705	115.850	52	52	7.470	6.867	-0.104	102	0.918
S-N-Sp	85.722	85.491	55	52	4.006	4.292	0.287	105	0.775
S-N-Ss	83.753	80.634	56	52	3.507	3.989	4.321	106	0.000
S-N-Pr	85.673	83.087	55	52	3.587	4.179	3.440	105	0.001
S-N-Id	82.291	80.301	56	52	3.396	4.092	2.758	106	0.007
S-N-Sm	80.600	78.346	57	52	3.302	3.923	3.254	107	0.002
S-N-Pg	82.369	80.017	57	52	3.590	3.932	3.264	107	0.001
S-N-Gn	79.370	76.841	57	52	3.446	3.923	3.583	107	0.001
PL/NSL	5.978	7.990	54	52	3.376	3.634	-2.954	104	0.004
ML/NSL	27.701	29.819	56	52	5.964	6.798	-1.724	106	0.088
ML/RL	120.626	121.772	64	52	7.626	7.069	-0.831	114	0.407
CL/ML	69.693	70.943	63	52	5.452	5.984	-1.171	113	0.244
RL/NSL	87.297	88.056	56	52	6.058	4.796	-0.718	106	0.474
RL/PL	98.454	99.746	60	52	5.845	4.497	-1.296	110	0.198
PL/ML	21.931	22.015	60	52	5.900	6.884	-0.070	110	0.945
ASL/PL	103.598	108.355	59	52	6.552	7.197	-3.645	109	0.000
ASL/NSL	98.828	100.653	56	52	8.372	7.294	-1.204	106	0.231
S-Ar-tGo	142.853	141.879	57	52	8.243	5.652	0.713	107	0.477
OL/NSL	12.024	12.460	25	52	5.300	4.367	-0.383	75	0.703
Ar-tGo-N	48.489	49.160	64	52	4.710	3.553	-0.849	114	0.398
N-tGo-Gn	72.138	72.603	64	52	4.991	5.850	-0.462	114	0.645
N-Ar/OL	30.823	30.163	28	52	4.756	4.023	0.657	78	0.513
N-Ss-Pg	177.234	178.587	64	52	5.642	5.055	-1.345	114	0.181
Ss-N-Sm	3.130	2.353	64	52	2.326	2.182	1.840	114	0.068
Pr-N-Id	3.466	2.741	62	52	1.928	1.422	2.246	112	0.027
S-Go%N-Gn	0.690	0.683	56	52	0.047	0.050	0.711	106	0.478
S-tGo%N-Gn	0.721	0.704	56	52	0.050	0.054	1.717	106	0.089
N-Sp%N-Gn	0.423	0.440	62	52	0.020	0.025	-4.046	112	0.000
+1/PL	104.779	108.964	38	52	7.593	7.060	-2.690	88	0.009
-1/ML	95.762	94.705	52	52	6.900	7.491	0.749	102	0.456
+1/-1	134.759	134.213	35	52	10.915	9.042	0.254	85	0.800
+1/NSL	99.083	101.261	34	52	8.578	7.233	-1.268	84	0.208
-1/NSL	55.793	55.517	46	52	7.507	6.883	0.190	96	0.850
Is-Ii	2.361	2.693	29	52	2.072	1.018	-0.968	79	0.336
Is+Ii	-0.249	2.487	29	52	1.883	1.757	-6.547	79	0.000

	Mean		N		SD				
Dimension	Mikulčice	Recent	Mik.	Recent	Mikulčice	Recent	t-value	df	p
Ss+Sm	0.950	1.630	28	52	2.294	2.989	-1.047	78	0.298
Pr+Id	2.849	2.453	27	52	2.410	1.818	0.819	77	0.415
Ss+Sm(modif.OL)	-0.588	-1.261	33	52	3.351	3.007	0.961	83	0.339
Pr+Id(modif.OL)	1.845	1.068	32	52	3.090	2.091	1.376	82	0.173

Table 6. Craniofacial comparison between Early Medieval and recent males (linear and shape characteristics of the neurocranium).

	Mean		N		SD				
Dimension	Mikulčice	Recent	Mik.	Recent	Mikulčice	Recent	t-value	df	p
N-S	68.267	69.481	57	52	3.221	2.950	-2.045	107	0.043
S-Ba	45.007	45.484	56	52	3.542	3.137	-0.737	106	0.463
G-Op	187.536	180.624	65	52	7.840	4.994	5.522	115	0.000
Ba-B	136.537	140.293	64	52	6.477	5.029	-3.426	114	0.001
N-B	112.638	114.500	65	52	5.138	5.202	-1.937	115	0.055
B-L	118.793	109.774	65	52	6.850	5.847	7.545	115	0.000
L-Op	28.679	41.658	52	52	7.174	6.648	10.135	118	0.000
L-Ba	116.469	115.286	64	52	5.896	4.964	1.152	114	0.252
N-L	178.718	172.194	65	52	7.100	4.600	5.731	115	0.000
N-I	174.417	174.176	65	52	8.318	5.649	0.179	115	0.859
G-L	181.014	173.846	65	52	7.405	4.769	6.046	115	0.000
G-I	180.507	180.588	65	52	8.666	5.716	-0.058	115	0.954
B-I	155.336	154.498	65	52	6.363	6.845	0.684	115	0.495
L-O	96.537	100.453	65	52	5.227	5.672	-3.877	115	0.000
L-NO	95.392	100.260	65	52	5.394	5.781	-4.698	115	0.000
Op-NO	72.678	78.895	65	52	5.717	7.399	-5.128	115	0.000
I-NO	35.904	41.658	65	52	5.797	6.648	-4.998	115	0.000
B-NL	73.330	71.663	65	52	4.767	4.943	1.849	115	0.067
Op-NL	28.803	28.051	64	52	6.874	7.858	0.549	114	0.584
I-NL	60.717	64.616	65	52	5.988	7.191	-3.200	115	0.002
N-B-O	61.091	59.857	65	52	2.848	2.119	2.600	115	0.011
N-L-O	49.421	53.385	65	52	2.528	2.313	-8.749	115	0.000
N-Op-O	43.340	49.162	65	52	2.609	2.782	-11.646	115	0.000
N-I-O	35.041	39.501	65	52	3.421	4.411	-6.161	115	0.000
N-B-L	101.149	100.396	65	52	3.552	3.703	1.117	115	0.266
N-Op-L	75.830	75.886	65	52	3.246	3.355	-0.092	115	0.927
N-I-L	83.485	77.286	65	52	4.113	3.876	8.310	115	0.000

Table 7. Craniofacial comparison between Early Medieval and recent females (linear dimensions of the face).

	Mean		N		SD				
Dimension	Mikulčice	Recent	Mik.	Rec.	Mikulčice	Recent	t-value	df	p
N-Rhi	17.452	23.025	52	36	3.489	4.132	-6.829	86	0.000
N-Sp	48.430	49.155	61	36	3.248	3.282	-1.058	95	0.293
N-Ss	52.657	53.178	60	36	3.340	3.628	-0.716	94	0.476
N-Pr	64.681	64.794	62	36	4.717	4.741	-0.114	96	0.909
N-Gn	112.646	109.785	63	36	7.491	7.735	1.807	97	0.074
N-Go	108.280	109.590	62	36	5.915	6.542	-1.017	96	0.312
Sp-Is	26.947	27.067	35	36	3.084	3.343	-0.157	69	0.875
Pr-Id	20.041	18.047	62	36	2.603	1.950	3.988	96	0.000
Ii-Gn	39.302	38.167	51	36	3.460	3.224	1.551	85	0.125
Id-Gn	29.629	28.476	63	36	3.198	2.901	1.783	97	0.078
Id-Sm	8.153	7.098	64	36	1.946	1.878	2.634	98	0.010
Sp-Pg	57.139	55.233	61	36	6.540	6.538	1.386	95	0.169
Sp-Pmp	47.424	51.025	61	36	2.930	2.901	-5.869	95	0.000
Ss-Pmp	45.952	45.473	60	36	2.557	2.256	0.928	94	0.356
Pmp-Ba	42.623	42.629	59	36	3.409	3.328	-0.008	93	0.994
S-Go	74.117	74.369	54	36	5.796	5.904	-0.200	88	0.842
S-Pgn	118.456	115.979	56	36	6.393	5.692	1.892	90	0.062
Cd-Go	53.858	55.240	61	36	4.710	4.855	-1.381	95	0.171
Pgn-Go	72.032	70.034	62	36	4.200	3.670	2.375	96	0.020
S-Ar	32.937	33.289	55	36	5.217	2.922	-0.368	89	0.714
Pmp-NSL	42.063	43.103	57	36	3.897	2.968	-1.369	91	0.174
Cd-NSL	19.272	17.582	59	36	4.508	2.819	2.019	93	0.046
Pr-PL	16.204	15.723	59	36	2.749	2.962	0.804	93	0.424
Mol-PL	23.297	21.641	48	36	3.355	2.062	2.612	82	0.011
Mol-ML	29.283	27.029	48	36	3.116	2.664	3.487	82	0.001
Pmp-VL	14.025	13.727	56	36	2.848	3.066	0.476	90	0.636
Ptm-VL	14.033	13.558	49	36	2.397	2.628	0.866	83	0.389
Ar-VL	18.102	18.373	55	36	2.953	3.094	-0.420	89	0.676

Table 8. Craniofacial comparison between Early Medieval and recent females (shape and dental characteristics of the face).

	Mean		N		SD				
Dimension	Mikulčice	Recent	Mik.	Recent	Mikulčice	Recent	t-value	df	p
N-S-Ba	130.494	130.937	54	36	4.618	5.624	-0.408	88	0.684
N-S-Cd	127.160	128.483	55	36	7.019	6.676	-0.896	89	0.373
N-S-Ar	123.829	123.659	55	36	5.554	5.577	0.143	89	0.887
N-S-Go	101.983	101.655	54	36	4.217	3.943	0.371	88	0.711
N-S-Pgn	66.593	66.511	56	36	3.842	4.570	0.092	90	0.927
S-N-Rhi	111.534	115.199	51	36	8.153	6.116	-2.281	85	0.025
S-N-Sp	85.495	87.195	54	36	4.389	4.647	-1.758	88	0.082
S-N-Ss	83.541	80.683	53	36	3.596	3.860	3.572	87	0.001

	Mean		N		SD				
Dimension	Mikulčice	Recent	Mik.	Recent	Mikulčice	Recent	t-value	df	p
S-N-Pr	85.966	83.772	54	36	3.383	3.888	2.839	88	0.006
S-N-Id	82.336	80.345	56	36	3.238	3.671	2.731	90	0.008
S-N-Sm	80.399	78.577	56	36	3.202	3.742	2.492	90	0.015
S-N-Pg	81.704	80.164	56	36	3.125	3.961	2.076	90	0.041
S-N-Gn	78.457	76.759	55	36	3.161	3.855	2.295	89	0.024
PL/NSL	6.973	6.676	54	36	3.512	3.127	0.410	88	0.683
ML/NSL	30.349	28.989	54	36	5.684	7.145	1.002	88	0.319
ML/RL	122.082	120.134	61	36	5.857	7.037	1.467	95	0.146
CL/ML	70.392	71.238	62	36	5.208	6.571	-0.703	96	0.484
RL/NSL	85.724	88.856	59	36	9.611	4.166	-1.849	93	0.068
RL/PL	97.712	97.914	61	36	12.422	4.568	-0.094	95	0.926
PL/ML	24.308	22.344	60	36	5.267	6.930	1.568	94	0.120
ASL/PL	107.176	112.333	56	36	6.806	7.431	-3.421	90	0.001
ASL/NSL	101.015	105.601	58	36	7.695	6.744	-2.941	92	0.004
S-Ar-tGo	145.312	145.176	55	36	7.623	5.569	0.092	89	0.927
OL/NSL	15.004	12.946	28	36	6.541	4.487	1.491	62	0.141
Ar-tGo-N	48.613	49.841	60	36	4.291	3.362	-1.467	94	0.146
N-tGo-Gn	73.317	70.291	60	36	5.051	6.179	2.611	94	0.011
N-Ar/OL	31.505	30.899	32	36	4.366	4.425	0.567	66	0.572
N-Ss-Pg	176.549	179.077	60	36	5.821	5.902	-2.050	94	0.043
Ss-N-Sm	3.023	2.106	60	36	2.538	2.213	1.796	94	0.076
Pr-N-Id	3.545	3.426	62	36	1.971	1.770	0.299	96	0.766
S-Go%N-Gn	0.659	0.679	53	36	0.044	0.054	-1.916	87	0.059
S-tGo%N-Gn	0.690	0.697	54	36	0.047	0.059	-0.631	88	0.529
N-Sp%N-Gn	0.431	0.449	60	36	0.024	0.025	-3.311	94	0.001
+1/PL	108.810	108.606	33	36	6.930	6.332	0.128	67	0.898
-1/ML	94.514	94.433	50	36	7.080	8.908	0.047	84	0.963
+1/-1	131.243	134.558	34	36	10.608	10.730	-1.299	68	0.198
+1/NSL	101.350	101.874	32	36	8.051	6.420	-0.299	66	0.766
-1/NSL	53.474	56.598	43	36	6.949	9.923	-1.640	77	0.105
Is-Ii	2.573	3.425	35	36	2.384	1.219	-1.905	69	0.061
Is+Ii	-0.216	2.958	34	36	1.869	1.561	-7.729	68	0.000
Ss+Sm	0.330	0.858	31	36	2.684	2.599	-0.816	65	0.417
Pr+Id	2.485	2.813	32	36	2.680	2.240	-0.550	66	0.584
Ss+Sm(modif.OL)	-0.890	-0.786	34	36	3.434	3.163	-0.132	68	0.895
Pr+Id(modif.OL)	2.014	1.962	35	36	2.894	2.539	0.080	69	0.937

Table 9. Craniofacial comparison between Early Medieval and recent females (linear and shape characteristics of the neurocranium).

	Mean		N		SD				
Dimension	Mikulčice	Recent	Mik.	Recent	Mikulčice	Recent	t-value	df	p
N-S	64.793	66.868	56	36	3.327	3.297	-2.931	90	0.004
S-Ba	41.144	41.486	54	36	2.639	2.758	-0.591	88	0.556
G-Op	179.793	173.982	62	36	6.407	8.345	3.865	96	0.000
Ba-B	130.948	134.924	58	36	5.337	5.201	-3.546	92	0.001
N-B	108.841	108.685	63	36	4.237	4.893	0.166	97	0.868
B-L	115.839	111.906	63	36	6.088	7.764	2.792	97	0.006
L-Op	27.361	44.489	62	36	7.315	6.710	11.512	96	0.000
L-Ba	112.713	112.357	58	36	5.203	6.374	0.296	92	0.768
N-L	172.741	168.133	63	36	6.154	8.307	3.148	97	0.002
N-I	166.204	166.650	60	36	6.785	7.260	-0.304	94	0.762
G-L	174.049	168.829	63	36	6.049	8.580	3.536	97	0.001
G-I	171.036	171.666	60	36	6.961	7.404	-0.419	94	0.676
B-I	149.278	148.663	60	36	6.658	7.107	0.427	94	0.670
L-O	95.027	97.900	60	36	5.338	5.212	-2.576	94	0.012
L-NO	93.587	97.855	60	36	5.580	5.193	-3.722	94	0.000
Op-NO	71.362	75.739	59	36	6.878	11.341	-2.345	93	0.021
I-NO	35.446	44.489	58	36	5.441	6.710	-7.156	92	0.000
B-NL	71.654	71.277	63	36	4.257	4.962	0.399	97	0.691
Op-NL	27.243	27.262	62	36	7.340	10.582	-0.011	96	0.991
I-NL	57.646	57.351	60	36	6.285	5.664	0.232	94	0.817
N-B-O	59.488	59.101	61	36	2.751	2.231	0.715	95	0.476
N-L-O	47.823	52.704	60	36	2.897	3.088	-7.798	94	0.000
N-Op-O	41.969	48.947	59	36	2.768	3.883	-10.205	93	0.000
N-I-O	35.034	43.300	58	36	4.067	4.572	-9.132	92	0.000
N-B-L	100.519	99.201	63	36	3.372	4.253	1.698	97	0.093
N-Op-L	76.821	79.019	62	36	3.376	3.224	-3.158	96	0.002
N-I-L	85.867	81.253	60	36	3.867	3.587	5.813	94	0.000

Table 10. The craniofacial comparison between Early Medieval and Neolithic populations (males).

	EMA Mikulčice (Male)			Neolithic (Male)				
	N	Mean	SD	N	Mean	SD	t	p
G-Op	65	187.536	7.840	9	184.100	6.210	1.258	
Ba-B	64	136.537	6.477	5	139.400	3.650	-0.972	
N-Pr	63	67.364	4.244	6	68.200	2.990	-0.470	
N-Gn	65	119.678	7.745	6	113.000	4.100	2.075	*

Table 11. The craniofacial comparison between Recent and Neolithic populations (males).

	Recent (Male)			Neolithic (Male)				
	N	Mean	SD	N	Mean	SD	t	p
G-Op	52	180.624	4.994	9	184.100	6.210	-1.861	
Ba-B	52	140.293	5.029	5	139.400	3.650	0.386	
N-Pr	52	69.855	4.030	6	68.200	2.990	0.972	
N-Gn	52	120.281	6.769	6	113.000	4.100	2.568	*

Table 12. The craniofacial comparison between Early Medieval and Neolithic populations (females).

	EMA Mikulčice (Female)			Neolithic (Female)				
	N	Mean	SD	N	Mean	SD	t	p
G-Op	62	179.793	6.407	8	178.300	6.960	0.615	
Ba-B	58	130.948	5.337	6	138.800	4.120	-3.488	***
N-Pr	62	64.681	4.717	4	59.500	4.200	2.140	*
N-Gn	63	112.646	7.491	2	100.500	0.710	2.276	*

Table 13. The craniofacial comparison between Recent and Neolithic populations (females).

	Recent (Female)			Neolithic (Female)				
	N	Mean	SD	N	Mean	SD	t	p
G-Op	36	173.982	8.345	8	178.300	6.960	-1.359	
Ba-B	36	134.924	5.201	6	138.800	4.120	-1.731	
N-Pr	36	64.794	4.741	4	59.500	4.200	2.137	*
N-Gn	36	109.785	7.735	2	100.500	0.710	1.675	

Table 14. The evaluation of differences between populations using linear dimensions of the skull (males). Explanatory notes: * 5% level of statistical significance; ** 1% level of statistical significance; *** 0,1% level of statistical significance.

Dimension	Anal. of Variance			Eneolithic		Bronz	Earl.M.Age	Recent
	F-test	p		Cord.W.C.	Bell Beak.C.	Unětice C.		
M1 (G-Op)	24.387	***	Mean	193.433	181.843	190.422	187.536	180.624
			N	30	51	154	65	52
			SD	7.740	9.186	8.790	7.840	4.994
			Scheffe Test					
			Cord.W.C.		***		*	***
			Bell Beak.C.	***		***	**	
			Unětice C.		***			***
			Earl.M.Age	*	**			***
			Recent	***		***	***	
M17 (B-Ba)	3.603	**	Mean	141.556	140.071	141.484	137.187	140.293
			N	9	28	93	65	52
			SD	6.766	7.039	7.452	8.293	5.029
			Scheffe T					
			Cord.W.C.					
			Bell Beak.C.					
			Unětice C.				**	
			Earl.M.Age			**		
			Recent					
M47 (N-Gn)	3.501	**	Mean	112.813	118.000	117.949	119.678	120.281
			N	16	23	59	65	52
			SD	8.368	6.564	7.973	7.745	6.769
			Scheffe T					
			Cord.W.C.				*	*
			Bell Beak.C.					
			Unětice C.					
			Earl.M.Age	*				
			Recent	*				
M48 (N-Pr)	4.163	**	Mean	67.267	70.210	70.074	67.364	69.855
			N	15	31	81	63	52
			SD	5.7379	4.5639	5.5154	4.244	4.0303
			Scheffe T					
			Cord.W.C.					
			Bell Beak.C.					
			Unětice C.				*	
			Earl.M.Age			*		
			Recent					
M55 (N-Sp)	4.455	**	Mean	49.563	50.563	51.326	50.588	52.936
			N	16	32	86	62	52
			SD	3.723	3.501	3.987	3.367	3.395

Dimension	Anal. of Variance			Eneolithic		Bronz	Earl.M.Age	Recent
	F-test	p		Cord.W.C.	Bell Beak.C.	Unětice C.		
			Scheffe T					
			Cord.W.C.					*
			Bell Beak.C.					
			Unětice C.					
			Earl.M.Age					*
			Recent	*			*	
M69 (Id-Gn)	4.155	**	Mean	31.563	33.200	34.489	32.154	32.193
			N	16	30	45	64	52
			SD	4.472	3.305	4.208	3.198	2.911
			Scheffe T					
			Cord.W.C.					
			Bell Beak.C.					
			Unětice C.				*	*
			Earl.M.Age			*		
			Recent			*		

Table 15. The evaluation of differences between populations using linear dimensions of the skull (females). Explanatory notes: * 5% level of statistical significance; ** 1% level of statistical significance; *** 0,1% level of statistical significance.

Dimension	Anal. of Variance			Eneolithic		Bronz	Earl.M.Age	Recent
	F-test	p		Cord.W.C.	Bell Beak.C.	Unětice C.		
M1 (G-Op)	9.932	***	Mean	183.867	174.429	181.533	179.793	173.982
			N	15	28	90	62	36
			SD	8.314	8.570	8.264	6.407	8.345
			Scheffe Test					
			Cord.W.C.		**			**
			Bell Beak.C.	**		**		
			Unětice C.		**			***
			Earl.M.Age					*
			Recent	**		***	*	
M17 (B-Ba)	7.459	***	Mean	135.800	136.412	136.519	130.948	134.924
			N	5	17	54	58	36
			SD	6.181	5.906	6.658	5.337	5.201
			Scheffe T					
			Cord.W.C.					
			Bell Beak.C.				*	
			Unětice C.				***	
			Earl.M.Age		*	***		*
			Recent				*	
M47 (N-Gn)	1.708		Mean	107.200	110.667	112.793	112.646	109.785
			N	5	12	29	63	36
			SD	6.301	4.228	5.846	7.491	7.735

Dimension	Anal. of Variance			Eneolithic		Bronz	Earl.M.Age	Recent
	F-test	p		Cord.W.C.	Bell Beak.C.	Unětice C.		
			Scheffe T					
			Cord.W.C.					
			Bell Beak.C.					
			Unětice C.					
			Earl.M.Age					
			Recent					
M48 (N-Pr)	0.743		Mean	66.800	64.882	65.958	64.681	64.794
			N	5	17	48	62	36
			SD	6.301	4.961	4.212	4.717	4.741
			Scheffe T					
			Cord.W.C.					
			Bell Beak.C.					
			Unětice C.					
			Earl.M.Age					
			Recent					
M55 (N-Sp)	1.305		Mean	46.833	47.188	48.551	48.430	49.155
			N	6	16	49	61	36
			SD	4.875	3.311	3.440	3.248	3.282
			Scheffe T					
			Cord.W.C.					
			Bell Beak.C.					
			Unětice C.					
			Earl.M.Age					
			Recent					
M69 (Id-Gn)	6.760	***	Mean	30.455	31.800	31.684	29.629	28.476
			N	11	20	38	63	36
			SD	3.532	3.622	2.762	3.198	2.901
			Scheffe T					
			Cord.W.C.					
			Bell Beak.C.					**
			Unětice C.				*	***
			Earl.M.Age			*		
			Recent		**	***		

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Anthropological and epidemiological characterization of Great-Moravian population in connection with the social and economic structure

The State of Dentition in the Great Moravian Population – a Comparison of the Mikulčice Centre and its Hinterland

Petra Stránská[1] – Petr Velemínský[2] – Jana Velemínská[3]

The state of dentition is affected not only by endogenous factors (e.g. genetic predispositions), but also by exogenous factors, such as the quality of diet, its processing, or infectious diseases and trauma associated, among others, with the socio-economic status of the given population group. Thus, it also indirectly testifies to the living conditions of our ancestors. In our paper, we evaluated the primary indicator of the state of dentition- caries associated lesions and intra-vital teeth loss in adult males and females from three Great Moravian localities, the Mikulčice-Kostelisko burial site, the first burial site at Prušánky and from Josefov. Mikulčice-Kostelisko, located in the the sub-castle area of Mikulčice castle represents a population, where a higher social status and thus better living conditions of the persons buried there may be presumed. Prušánky and Josefov are burial sites in the Mikulčice centre hinterland. The group from Josefov is considered to be a peasant population, i.e. the poorer section of the inhabitants. In the case of Prušánky, taking into consideration the grave equipment, a peasant character of the inhabitants cannot be ruled out. Nonetheless, individuals with a richer grave inventory were also buried at this site. We used two indexes in our evaluation- the Index of Caries Frequency F-CE and the Index of Intensity of Caries I-CE. We correlated the incidence of caries and intra-vital loss with sex and age, for each burial site separately, and we subsequently compared the individual burial sites, also taking into consideration the presumed socio-economic status of the given population. We also verified the differences between the graves with poor and rich grave inventory. As expected, at all burial sites, females were more often affected than males. We determined significant differences only in the incidence of intra-vital losses. The correlation between the degree of affliction and age was confirmed. Significantly greater incidence of caries was recorded in individuals from poorer graves compared to individuals from richer graves. The socio-economically privileged Kostelisko population was characterised by less caries than both village populations.

Keywords: state of dentition – Great Moravian population – index of caries frequency – index of intensity of caries – socio-economic comparison – grave goods

1. Introduction

Dental anthropology – the study of the state of dentition – is today an integral part of the analysis of the skeletal remains of past populations. The state of dentition is affected not only by endogenous factors (e.g. genetic predispositions) (Fig. 5), which we are generally unable to grasp, but also by exogenous factors, such as the quality of diet, its processing or infectious diseases and trauma associated, among others, with the socio-economic status of the given population group. Thus, it also indirectly testifies to the living conditions of our ancestors. In view of the aforementioned "multi-factorial" aetiology, these results cannot be interpreted unequivocally. For example, we must always keep in mind the clear correlation of the state of dentition with biological age.

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Table 1. Dental disease (created from KILIAN at al. 1999).

Teeth disease (hard tissue, pulp, periodont)				Parodontal disease	
Developmental		Acquired			
Type of disease	Possible causes	Type of disease	Possible causes P	Type of disease	Possible causes
hypoplasia	genetics, the maternal organism disease within the prenatal development, inflammatory, trauma	**caries**	infection, genetics, diet, dental attrition, dental abrasion, trauma, sex, age	**inflammation of gingival tissue**	infection, genetics, trauma, age, sex
dysplasia (fluorosis, amelogenesis imperfecta)		**intravital loss**		**parodontitis**	
hypomineralization		**pulpitis**		**parodont atrophy**	
tooth count variation (anodontia, hypodontia, hyperdontia)		**periodontitis**			
tooth size variation (mikrodontia, makrodontia)					
retention					
malocclusion					
tooth shape variation					
transposed teeth					

Table 2. Evaluated dentitions in each cemeteries.

	No. of individuals	No. of permanent teeth	No. of dental alveolus	No. of intravital losses	No. of postmortal losses	No. of retentions
Mikulčice-Kostelisko	208	3455	4996	565	969	7
Prušánky	121	1819	2929	583	529	0
Josefov	48	640	1060	169	251	0

Table 3. Demographic characterization of evaluated individuals.

	20-35	35-50	Over 50 years	In total
Mikulčice-Kostelisko				
male	25	41	13	79
female	62	55	12	129
in total	87	96	25	208
Prušánky				
male	5	26	14	45
female	20	37	19	76
in total	25	63	33	121
Josefov				
male	2	7	7	16
female	5	12	15	32
in total	7	19	22	48

We may divide the pathological states of dentition into two basic groups- diseases affecting the tooth itself and including hard tissues, pulp and the periodontium, and diseases of the parodontium (tissues associated with the tooth topographically or functionally). We then divide tooth defects into developmental and acquired. With the exception of congenital, hereditary defects, all other entities may indicate the degree of living condition optimality (Table 1).

Compared to classical osteology, the study of dentition has several advantages. Teeth are often preserved intact, i.e. they usually represent, from a statistical point of view, an adequate sample for the evaluation at the level of population groups. The quality of diet, eating habits have always been associated with the social status of a given population group. In the case of the Great Moravian burial sites studied, we thus attempted to evaluate dental pathologies in such a context. The data acquired thus creates a solid odontological database that makes the comparative analysis with other populations possible.

2. Materials

Our paper is devoted to the evaluation of the primary indicators of the state of dentition- lesions of caries and intra-vital tooth loss- in adult individuals from the Mikulčice-Kostelisko burial site, from the first burial site at Prušánky and from the burial site at Josefov. Periodontal disease (granulomas, abscesses) will be the subject of further research (Fig. 2, 5). Hypoplastic enamel defects have been published independently (e.g. Trefný/Velemínský this book, pp. 141-149). These burial sites have not as yet been processed archaeologically, or if they have been, then they not as yet been published.

Mikulčice-Kostelisko (henceforth Kostelisko) (9th-10th century) is the second largest Great Moravian burial site, located in the sub-castle area of Mikulčice castle. There is an assumption that is the burial site of the inhabitants of the fore-castle (peasants, artisans and members of the higher social classes) (Poláček/Marek 1995;

Fig. 1. Josefov – grave 23. Intravital loss of major part of the mandibular teeth.

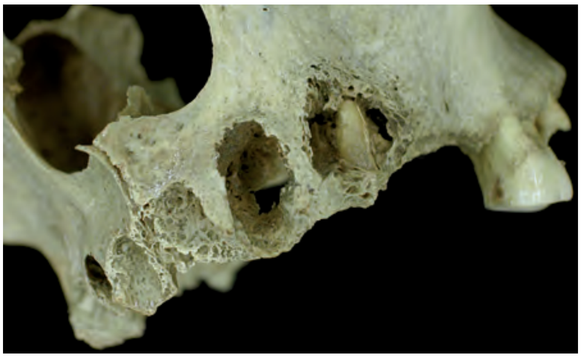


Fig. 2. Josefov – grave 70. Periapical lesions on roots of left second incisor and canine.

Fig. 3. Josefov – grave 70. Intravital loss of all right half maxillary teeth.

Fig. 4. Mikulčice – grave 1776. Probably posttraumatic intravital loss of both upper right incisors (the state of health of the other teeth is very good).

Fig. 5. Mikulčice – grave 2000. Large periapical lesion on roots of left upper molars.

Fig. 6. Prušánky – grave 150. Dental carries on right upper second molar. Rotation of right upper canine.

Velemínský et al 2005). Out of the 420 graves, we evaluated the state of dentition in 79 males and 129 females.

Prušánky lie around 9 km as the crow flies from Mikulčice castle. Six hundred seventy six graves dating to the Early Medieval Age, i.e. the Great Moravian period (9th-10th century – rural character of grave equipment, so-called "Prušánky1") and to the Late 'Hilfort' period (11th-12th century, richer grave equipment, so-called "Prušánky II") (e.g. Klanica 1977, 1980). The poorer character of grave equipment at the Prušánky I burial site indicates that this could have been a village burial site. Of the whole group that included 330 graves, there were 176 adults. We were able to assess dentition in 134 adult individuals, of which 45 were males and 76 females.

The archaeological research of the **Josefov** burial site was conducted by Eva Šráčková from the Institute of Archaeology of the Czech Academy of Science, Brno, between 1958 and 1961. One hundred seventy six uncovered graves were dated to the second half of the 9th century. This is a village burial site (Hanáková/Stloukal 1966), whereby we assessed the dentition of 16 males and 32 females out of the 167 individuals buried there (e.g. Stránská et al. 2002).

Thus, this study includes these localities with the following number of evaluated teeth and alveoli. In the case of retention, the third molars were not included, as molars were not x-rayed (Table 2).

The state of preservation of the material studied is characterised by two indexes – the comparative dental index (CDI) and the comparative alveolar index (CAI). The comparative dental index could correlate with the group quantity, while no such correlation could be found in the case of the comparative alveolar index, and it is thus more of an indicator of the overall preservation of the material (Stloukal 1963, Stloukal/Vyhnánek 1976). The values of our material were as follows – Kostelisko - CDI 66.5, CAI 75.1, Prušánky - CDI 60.6, CAI 75.6, and Josefov - CDI 58.0, CAI 69.0. The worst preservation involved the material from Josefov.

The basic demographic characteristics of the evaluated adult males and females are listed in Table 3. As we had at our disposal an adequate number of dentitions, enabling statistical evaluation, we did not include individuals who could not be identified in our calculations.

3. Methods

On the dentition of adult males and females, we evaluated the incidence of caries and intra-vital loss. Both characteristics can be easily observed macroscopically (Fig. 1, 3, 6, 7, 8, 9). In the case of carious lesions, we took into consideration only clear cavities and not microscopically white or brown blemishes immediately below the surface layer of enamel, which indicate the initial phase of caries (Hillson 1996). The consequence of caries is the progressive destruction of dental structures by bacteria, which over time leads to intra-vital loss. On the other hand, intra-vital loss need not always be caused by progressive caries. The absence of teeth may also be the consequence of an accident. This most often involves the front teeth (Fig. 4). Naturally, though, we were unable to recognise this, and thus we did not take this possibility into consideration in our evaluation. In our observations, we did not evaluate the third molars, in view of the difficulties ensuing from their equivocal presence or absence (Caselitz 1998).

We used the Index of Caries Frequency F-CE, which expresses the proportional representation of individuals (or rather the skulls studied) whose dentition has at least one caries or intra-vital loss, for our evaluation. Another indicator that informs about the overall number of teeth with caries out of the number of teeth found and about the number of healed alveoli following intra-vital loss out of the total number of preserved alveoli is the Index of Intensity of Caries I-CE. This index thus represents the sum of the percentage values of the incidence of caries and the incidence of intra-vital losses. In the case of very poor material preservation and the concurrent high degree of caries, the value of this index may reach truly illogical

Fig. 7. Prušánky – grave 42. Intravital loss of all mandibular teeth.

Fig. 8. Prušánky – grave 97. Dental caries on right lower molars.

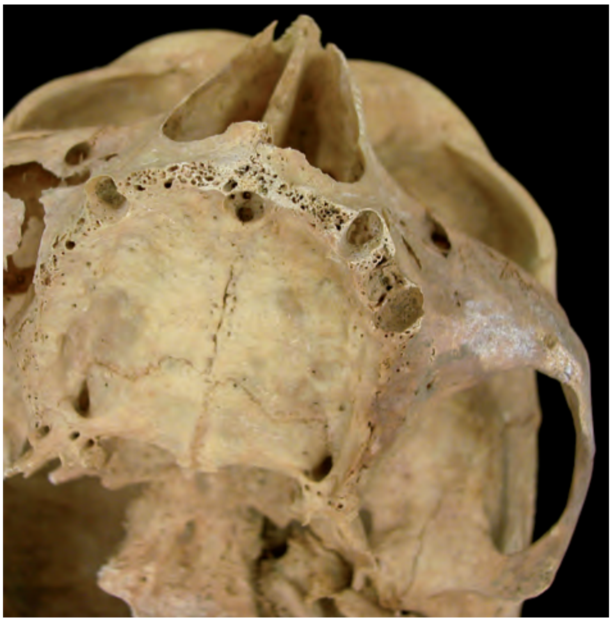
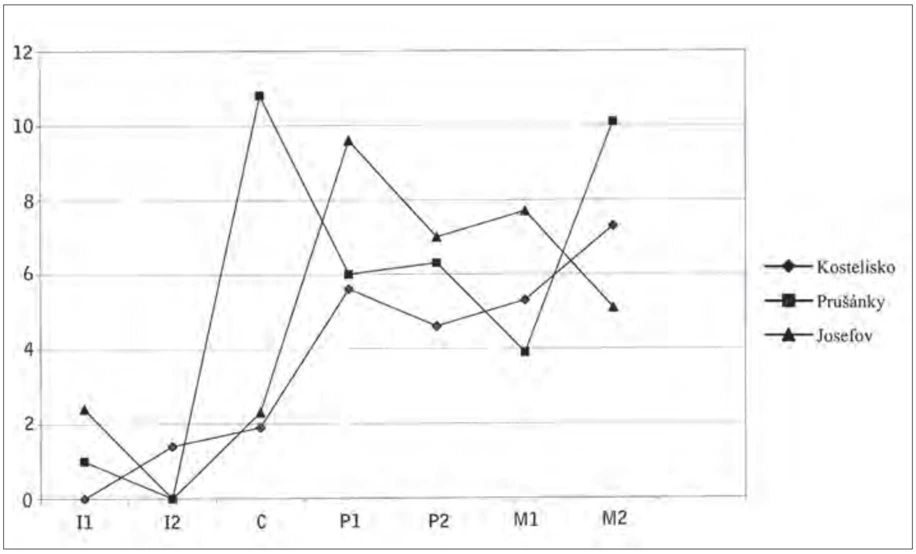
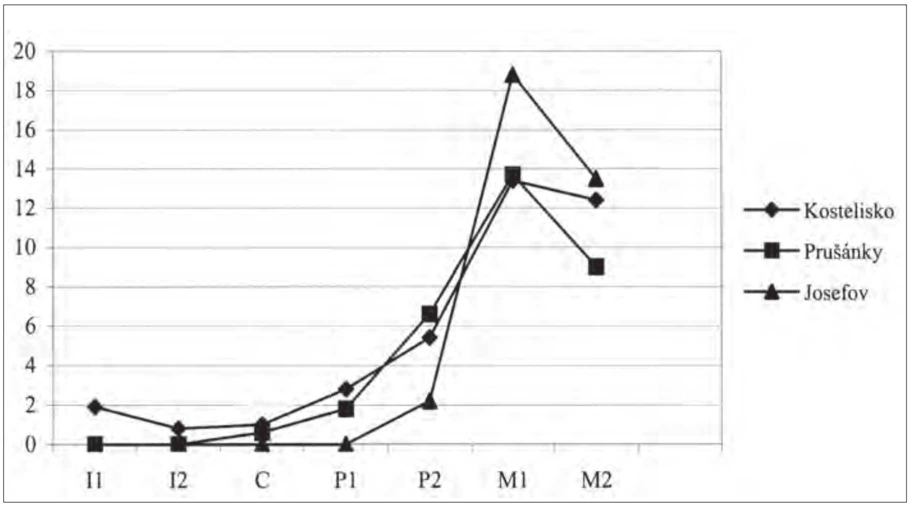


Fig. 9. Prušánky – grave 159. Intravital loss of nearly all maxillary teeth.

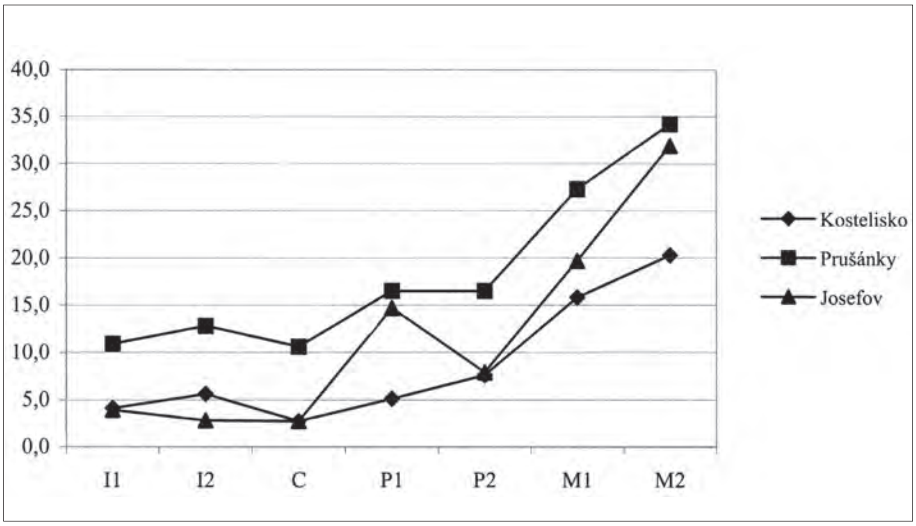


Graph 1. Dental caries in the individual teeth in maxila – adults.

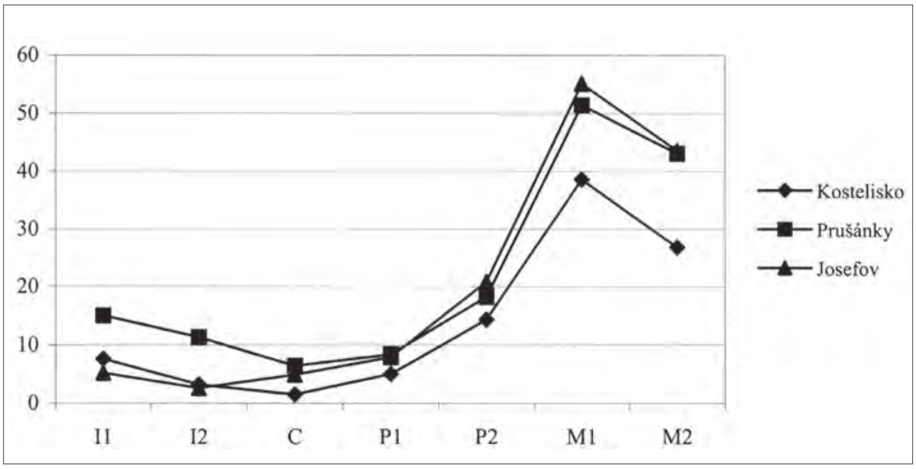


Graph 2. Dental caries in the individual teeth in mandible – adults.

values exceeding 100.0 (Stránská/Likovský/Velemínská 2005). Some researchers use only the expression of the proportion of carious teeth and the proportion of intra-vital losses in percent, without adding both values (e.g. Šlaus 2000, 2002). Other researchers use this index routinely to express the degree of teeth caries (e.g. Stloukal/Vyhnánek 1976; Caselitz 1998; Beňuš/Thurzo 2001; Bodoriková/Drozdová 2005; Bodoriková/Thurzo/Drozdová 2005). When using this method of evaluation of the incidence of caries and intra-vital losses, the result may be significantly influenced by the state of preservation of individual types of teeth, as molars are usually more affected by caries than front teeth, and molars are better and more often preserved. Thus, in the case of absence or poor preservation of the front teeth, there is a significant artificial increase in the proportion of carious lesions (Hillson 1996, Duyar/Erdal 2003). At the burial sites studied, though, all types of teeth were more or less uniformly represented, as shown in Tables 4-6. We thus presume that there was no significant distortion of results. There exist many various approaches and methods for evaluating dental caries (e.g. the Caries Rate calculation for every type of tooth, or the classical DM Index, Hardwick's correction, calculating by J.R.Lucacs 1995), which also depend on other factors (e.g. also on the manner of evaluation, what is included among the carious lesion) and are still the subject of much discussion (e.g. Costa 1980; Saunders/De Vito/Katzenberg 1997; Hillson 2001; Duyar/Erdal 2003). None of these methods is



Graph 3. Intravital loss in the individual teeth in maxila - adults.



Graph 4. Intravital loss in the individual teeth in mandible - adults.

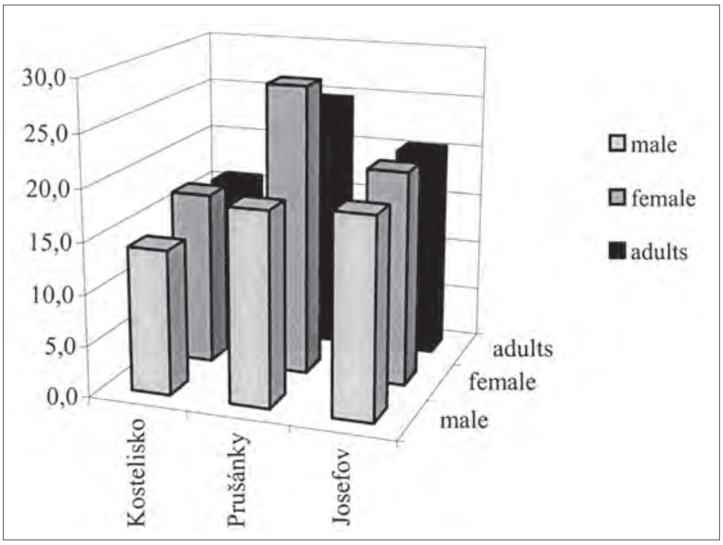
to date considered to be sufficiently precise. In our opinion, the greatest problem ensuing from such different approaches is the fact that it is impossible to compare different groups without revising and correcting the initial data.

We correlated the incidence of caries and intra-vital loss with sex and age, separately for each burial site. We subsequently compared the individual burial sites. We also compared the Mikulčice-Kostelisko population (where we presumed a higher social status) with the remaining burial sites of the Mikulčice hinterland – Josefov and Prušánky I (where we presumed a rural or peasant population). We also verified the differences between the graves with poor and rich grave inventories (Velemínský 2000) within each burial site. We consulted the statistical evaluation with RNDr. Karel Zvára, CSc. To test the null hypothesis, namely that cariousness of teeth does not differ among individual age categories, between the sexes and between poor and rich graves, we created contingency tables of nominal quantities, and we used Pearson's $\chi 2$ -test for the calculation. We considered the difference to be significant if $p \leq 0.05$, and highly significant if $p \leq 0.001$. We used the STATISTICA version 6 program for our calculations.

4. Results

4.1 Cariousness of individual types of teeth (Tables 4-6, Graphs 1-4)

The cariousness of individual teeth was generally quite diverse, ranging from 0.0% (mostly incisors) to 57.1% (M1 in females at Josefov). In all groups, the number of intra-vitally lost teeth



Graph 5. I-CE in all cemeteries.

exceeded the number of carious teeth, in the case of both jaws. It must be remembered here that most intra-vital losses of the front teeth are of mechanical origin, not as the consequence of caries. In the case of the upper jaw, the second molar was most frequently lost during life. In the case of the mandible, the first molar was the most frequently lost tooth, without exception. Overall, more intra-vital losses were located on the mandible, significantly so in females at all burial sites (Prušánky $p \leq 0.05$, Josefov and Kostelisko $p \leq 0.001$), and in males at Kostelisko ($p \leq 0.01$).

4.2 Frequency of caries (Tables 7-9)

Another analysed parameter was the number of affected individuals considering the overall number of individuals studied that is the frequency of caries expressed with the aid of the F-CE index.

The frequency of caries was highest in the case of Prušánky (79,4%), followed by Kostelisko (75,5%) and the least number of affected individuals was discovered at Josefov (69,2%). The uncovered data show that significantly more females were affected than males at all the burial sites. The values of the index increased only moderately with age. No statistically significant increase was recorded in males, while in females a significant difference was found at all the localities studied (Prušánky $p \leq 0.05$, Josefov $p \leq 0.05$, Kostelisko $p \leq 0.001$), mainly thanks to the proportional increase of females with intra-vital loss at a higher age.

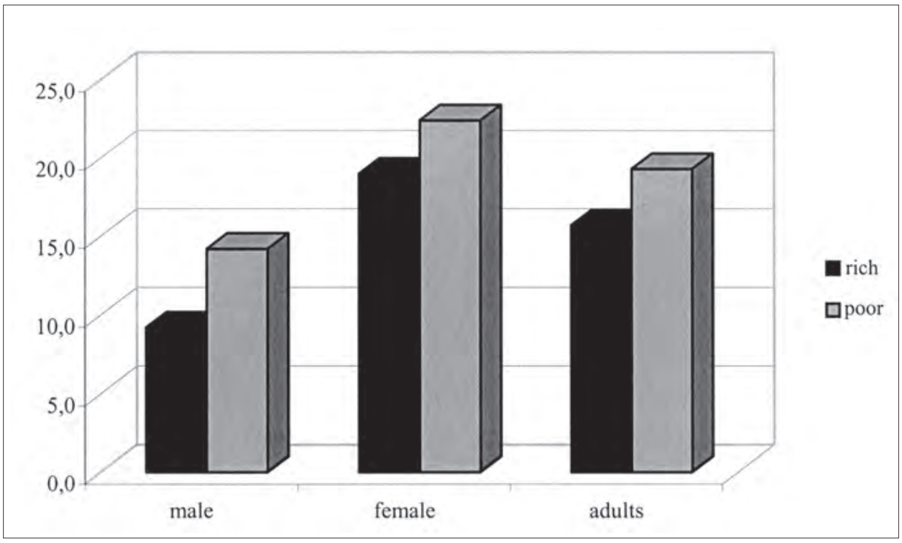
4.3 Caries intensity (Tables 10-12)

The amount of affected teeth and alveoli is characterised by the Index of Caries Intensity I-CE. We confirmed the hypothesis that the dentition of females is more affected by caries and intra-vital loss than that of males. Overall, we recorded the highest intensity of caries at Prušánky (24.7), followed by Josefov (20.4) and the most favourable situation was at Kostelisko (15.8).

As expected, our observation of the differences between individual age categories showed in all cases an increase in the value of the index with increasing age. This is associated with the increasing proportion of intra-vital loss, which at all burial sites was significantly higher in both sexes ($p \leq 0.001$), while the number of carious teeth showed an insignificant rising tendency, with the exception of females from Kostelisko ($p \leq 0.001$).

4.4 Comparison from the aspect of social status (Graph 5)

We based ourselves in our evaluation on the premise that the inhabitants buried at Kostelisko represent the middle and higher social classes, while those buried at Josefov and probably also at Prušánky were peasants and villagers. Of all the



Graph 6. I-CE in rich and poor graves – all burial grounds together.

parameters studied, we only found a significantly lower proportion of intra-vital loss in males and females at Kostelisko (p≤0.001) in both higher age categories, above 35. We reached the same results when we compared Kostelisko and the merged burial sites at Josefov and Prušánky.

4.5 Comparison of rich and poor graves according to the grave inventory (Tables 13-15, Graph 6)

We used Hrubý's five-grade classification (1955) and the more general Stloukal classification (1970) to determinate the graves (Velemínský 2000). Rich graves contained earrings, swords, axes, and other gold and silver objects, while poor graves contained for example vessels, whirls, beads, knives, flints, blades or they completely lacked any findings. We thus acquired two groups, which we could further subject to a comparative analysis. In view of the smaller numbers in the groups, we merged persons from individual age categories together.

In 31 rich graves from Prušánky (6 males, 25 females), we were able to assess 543 teeth, 802 preserved alveoli; in 17 graves from Josefov (6 males, 11 females) 233 teeth, 342 alveoli; and in 66 rich graves from Kostelisko (27 males, 39 females) 1238 teeth and 1602 alveoli.

A statistically significant difference in the number of intra-vital losses in both sexes was found in the case of all burial sites. When all burial sites were combined, we found significant differences between rich and poor graves, as well as in the number of carious lesions in both sexes (p≤0.05) and highly significant differences (p≤0.001) in the number of intra-vital losses.

5. Discussion and conclusion

The aim of our study was to evaluate the state of dentition in three Great Moravian populations in relation to the socio-economic structure of the given society. Mikulčice-Kostelisko represents a burial site in the sub-castle area of Mikulčice castle. It thus represents a population, where a higher social status and thus better living conditions of the persons buried there may be presumed. Prušánky and Josefov are burial sites in the hinterland of the Mikulčice centre. The group from Josefov is considered to be a peasant population, i.e. the poorer section of the population. In the case of Prušánky, given the grave equipment, a peasant character of the population cannot be ruled out. Nonetheless, individuals with a richer grave inventory are also buried here.

As to the sensitivity of individual teeth to the development of caries, the upper and lower jaws differed from each other. While in the case of the upper jaw, the most frequently affected teeth were not only the second molars but also the canines and premolars, in the case of the mandible, the most carious teeth included the first and second molars. Usually, canines or premolars are not completely destroyed during life, thus intra-vital loss involved most often the first (in the case of the lower jaw) or the second molars (in the case of the upper jaw). Overall, in all the localities studied, the mandible was more affected, significantly so in females at all burial sites and males at Kostelisko. Similar data has been reported by a number of researchers in the case of variously dated series from all over the world (Stloukal 1963; Caselitz 1998; Hillson 1996; Beňuš/Thurzo 2001).

The degree of caries frequency F-CE is more or less homogenous in both sexes, ranging in males from 68.8% to 79.9% and in females from 72.2% to 81.3%. Very similar data has been reported from other Slavic burial sites on the territory of Bohemia (e.g. Lahovice, Libice), Moravia (e.g. Rajhard, Pohansko) and Slovakia (Nitra-Pod Zoborom, Nitra-Lupka, Děvín-Za kostelem, Závada-Chriby, Pobedim-Hradiště) (Hanáková/Stloukal 1987; Hanáková/Staňa/Stloukal 1986; Bodoriková/Thurzo/Drozdová 2005; Thurzo et al 2002). I. Jarošová (2003) also analyzed the similar data of cariousness from many Bohemia, Moravia and Slovakia localities (some from 9th-10th century) in her comparative study.

In the case of all burial sites, females were affected insignificantly more often. This trend is also apparent in most of the other localities, but it is not the rule. We confirmed a slight increase in the number of affected individuals with age. This reached a significant difference in the case of females at all three burial sites.

From the aspect of caries intensity, I-CE, males appeared to represent a more homogenous group. The values acquired do not diverge from the data reported from other Slavic burial sites.

Overall, females were affected more often than males. Significant differences related to the proportion of intra-vital losses. A correlation between the degree of dentition involvement and age was shown, with a significant increase in the proportion of intra-vital loss in both sexes at all burial sites as well as in the proportion of caries in females at Kostelisko.

We also examined, whether there exist differences between socially differentiated groups, which were represented on the one hand by Kostelisko and on the other by Josefov and Prušánky, and whether such differences also exist within the individual burial sites between rich and poor graves. Although the interpretation is not unequivocal, different eating habits that can also influence the development of dental caries may be presumed in the different population classes.

Specialised literature does not provide much information regarding the diet of old Slavs. There is no doubt, though, that this diet was based on the products of agricultural crops. The main food was wheat and rye bread. Millet pudding and oatmeal were also a frequent meal. Honey or dried fruit were used for sweetening. Milk and dairy products as well as the meat of domestic animals were an equivalent component of diet. As reported by Beranová (1988, 2005), "at first, the members of the higher social classes did not differ by the fact that they ate much more meat, but by the fact that they ate different meat and that they were partial to its more complex and demanding preparation". Also, game, poultry and rare fruit found their way more often to their table. Such a combination of starches and sugars is highly cariogenic. On the other hand, milk, dairy products, animal fats are associated with a lower incidence of caries (e.g. Costa 1980; Mundorff-Shreshsta et al 1994; Hillson 1996). A rougher diet may reduce the incidence of caries, softer food, on the other hand, supports caries formation (Hillson 2001).

Among the groups compared, we did not find any significant differences in the F-CE indicator. As to the individual components of caries intensity, I-CE, a statistically insignificant difference was found in the amount of caries uncovered, while the proportion of intra-vitally lost teeth was significantly lower in middle-aged and older males and females from Kostelisko. These findings show that socially differentiated population groups did not show a different propensity to the development of caries in the younger age categories, with significant differences appearing only with increasing age. The socio-economically higher Kostelisko population was characterised by lower cariousness, compared with both rural populations. Similarly, lower cariousness was found in individuals from rich graves at all the studied burial sites. These differences may be associated not only with different diet, but also with different hygiene or with practices relating to the "maintenance" of carious teeth (e.g. pulling out of affected teeth). However, we do not have at our disposal information regarding the cultural behaviour of old Slavs that could influence the state of dentition. Beňuš/Thurzo (2001) compared the early Middle Age castle population of Děvín-Hrad with the Great Moravian peasant nobility from Děvín-Za kostelem. Contrary to our findings, these authors found an insignificant higher cariousness of dentition in the castle population, whom they expected to be of higher social status and thus their diet and food to be softer and richer in saccharides, while the peasants living beyond the stronghold walls lived on a rougher and thus less carious diet.

The data acquired represent the basis for a database for further research in the field of dental anthropology. Further research including the evaluation of caries position, abscesses, enamel hypoplasia, traumatic lesions of teeth and jaws or teeth abrasion is a prerequisite for acquiring basic information regarding the influence of ecological aspects on the state of dentition in Great Moravian populations.

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Table 4. Dental caries and intravital loss in the individual teeth and jaws – Mikulčice-Kostelisko.

	Teeth	Male			Female			Male+Female		
		N	Caries	%	N	Caries	%	N	Caries	%
maxilla	I1	69	-	0,0	102	-	0,0	171	-	0,0
	I2	79	1	1,3	130	2	1,5	209	3	1,4
	C	107	1	0,9	149	4	2,7	256	5	1,9
	P1	114	5	4,4	152	10	6,6	266	15	5,6
	P2	118	8	6,8	163	5	3,1	281	13	4,6
	M1	109	6	5,5	157	8	5,1	266	14	5,3
	M2	91	4	4,4	154	14	9,1	245	18	7,3
	in total	687	25	3,6	1007	43	4,2	1694	68	4,0
mandible	I1	69	0	0,0	136	4	2,9	205	4	1,9
	I2	96	0	0,0	166	2	1,2	262	2	0,8
	C	117	1	0,9	181	2	1,1	298	3	1,0
	P1	108	0	0,0	178	8	4,5	286	8	2,8
	P2	96	5	5,2	163	9	5,5	259	14	5,4
	M1	85	9	10,6	117	18	15,4	202	27	13,4
	M2	108	13	12,0	141	18	12,7	249	31	12,4
	in total	679	28	4,1	1082	61	5,6	1761	89	5,0
	alveoli	Male			Female			Male+Female		
		N	Intrav. loss	%	N	Intrav. loss	%	N	Intrav. loss	%
maxilla	I1	134	3	4,0	210	9	4,3	344	12	4,1
	I2	131	6	7,9	208	14	6,7	339	20	5,6
	C	140	4	2,9	209	6	2,9	349	10	2,7
	P1	138	5	3,6	207	14	6,8	345	19	5,1
	P2	137	7	5,1	208	20	9,6	345	27	7,6
	M1	136	19	13,9	202	36	17,8	338	57	15,8
	M2	123	29	23,6	196	34	17,3	657	63	20,3
	in total	940	73	8,8	1440	119	8,3	2380	208	8,6
mandible	I1	129	8	6,2	239	20	8,4	368	28	7,6
	I2	133	4	3,0	240	8	3,3	373	12	3,2
	C	141	1	0,7	248	5	2,0	389	6	1,5
	P1	135	4	2,9	245	15	6,1	380	19	5,0
	P2	135	21	15,6	235	32	13,6	370	53	14,3
	M1	138	43	31,1	232	100	43,1	370	143	38,6
	M2	141	28	19,9	225	70	31,1	366	98	26,8
	in total	952	109	11,4	1664	250	15,0	2616	359	13,7

Table 5. Dental caries and intravital loss in the individual teeth and jaws – Prušánky.

	Teeth	Male			Female			Male+Female		
		N	Caries	%	N	Caries	%	N	Caries	%
maxilla	I1	37	-	0,0	65	1	1,5	102	1	1,0
	I2	39	-	0,0	59	-	0,0	98	-	0,0
	C	60	9	15,0	88	7	7,9	148	16	10,8
	P1	61	4	6,7	88	5	5,7	149	9	6,0
	P2	58	3	5,2	84	6	7,1	142	9	6,3
	M1	47	-	0,0	81	5	6,2	128	5	3,9
	M2	39	2	5,1	70	9	12,9	109	11	10,1
	in total	341	18	5,3	535	33	6,2	876	51	5,8
mandible	I1	43	-	0,0	64	-	0,0	107	-	0,0
	I2	54	-	0,0	80	-	0,0	134	-	0,0
	C	67	-	0,0	109	1	0,9	176	1	0,6
	P1	65	1	1,5	104	2	1,9	169	3	1,8
	P2	61	4	6,6	90	6	6,7	151	10	6,6
	M1	37	5	13,5	58	8	13,8	95	13	13,7
	M2	43	3	6,9	68	7	10,3	111	10	9,0
	in total	370	13	3,5	573	24	4,2	943	37	3,9
	alveoli	Male			Female			Male+Female		
		N	Intrav. loss	%	N	Intrav. loss	%	N	Intrav. loss	%
maxilla	I1	75	3	4,0	135	20	14,8	210	23	10,9
	I2	76	6	7,9	135	21	15,6	211	27	12,8
	C	82	1	1,2	135	22	16,3	217	23	10,6
	P1	82	6	7,3	136	30	22,1	218	36	16,5
	P2	78	8	10,3	128	26	20,3	206	34	16,5
	M1	75	23	30,7	119	30	25,2	194	53	27,3
	M2	69	27	39,1	115	36	31,3	184	63	34,2
	in total	537	74	13,8	903	185	20,5	1440	259	17,9
mandible	I1	74	2	2,7	139	30	21,6	213	32	15,0
	I2	75	0	0,0	138	24	17,4	213	24	11,3
	C	76	0	0,0	142	14	9,9	218	14	6,4
	P1	76	1	1,3	139	17	12,2	215	18	8,4
	P2	76	9	11,8	138	30	21,7	214	39	18,2
	M1	76	38	50,0	136	71	52,2	212	109	51,4
	M2	75	30	40,0	129	58	44,9	204	88	43,1
	in total	528	80	15,2	961	244	25,4	1489	324	21,8

Table 6. Dental caries and intravital loss in the individual teeth and jaws – Josefov.

	Teeth	Male			Female			Male+Female		
		N	Caries	%	N	Caries	%	N	Caries	%
maxilla	I1	19	1	5,3	22	-	-	41	1	2,4
	I2	14	-	0,0	30	-	-	44	-	0,0
	C	17	-	0,0	27	1	3,7	43	1	2,3
	P1	18	2	11,1	34	3	8,8	52	5	9,6
	P2	22	3	13,6	35	1	2,9	57	4	7,0
	M1	18	2	11,1	34	2	5,9	52	4	7,7
	M2	11	1	9,1	28	1	3,6	39	2	5,1
	in total	119	9	7,6	210	8	3,8	329	17	5,2
mandible	I1	14	-	0,0	31	-	0,0	45	-	0,0
	I2	16	-	0,0	33	-	0,0	49	-	0,0
	C	22	-	0,0	34	-	0,0	56	-	0,0
	P1	18	-	0,0	29	-	0,0	47	-	0,0
	P2	16	-	0,0	29	1	3,4	45	1	2,2
	M1	11	1	9,1	21	5	23,8	32	6	18,8
	M2	13	2	15,4	24	3	12,5	37	5	13,5
	in total	110	3	2,7	201	9	4,5	311	12	3,9
	alveoli	Male			Female			Male+Female		
		N	Intrav. loss	%	N	Intrav. loss	%	N	Intrav. loss	%
maxilla	I1	27	-	0,0	49	3	6,1	76	3	3,9
	I2	26	-	0,0	46	2	4,3	72	2	2,8
	C	27	-	0,0	48	2	4,2	75	2	2,7
	P1	27	5	18,5	48	6	12,5	75	11	14,7
	P2	28	2	7,1	48	4	8,3	76	6	7,9
	M1	25	5	20,0	46	9	19,6	71	14	19,7
	M2	25	11	44,0	44	11	25,0	69	22	31,9
	in total	185	23	12,4	329	37	11,2	514	60	11,7
mandible	I1	21	-	0,0	56	4	7,1	77	4	5,2
	I2	20	-	0,0	58	2	3,4	78	2	2,6
	C	26	-	0,0	56	4	7,1	82	4	4,9
	P1	22	1	4,5	54	5	9,3	76	6	7,9
	P2	22	2	9,1	55	14	25,5	77	16	20,8
	M1	22	11	50,0	56	32	57,1	78	43	55,1
	M2	23	10	43,5	55	24	43,6	78	34	43,6
	in total	156	24	15,4	390	85	21,8	546	109	20,0

Table 7. F-CE – Mikulčice-Kostelisko. Frequency of caries.

Sex	Age	N	Caries (c.)		Intrav. loss		c.+i.l.		F-CE
			n	%	n	%	n	%	
males	20-35	25	5	20,0	4	16,0	5	20,0	56,0
	35-50	41	5	12,2	11	26,8	16	39,0	38,9
	over 50 years	13	-	-	4	30,8	7	53,8	84,6
	in total	79	10	12,7	19	24,1	28	35,4	72,2
	20-35	62	14	22,6	12	19,4	13	20,9	62,9
females	35-50	55	6	10,9	27	49,1	16	29,1	89,1
	over 50 years	12	-	-	6	50,0	6	50,0	100,0
	in total	129	20	15,5	45	34,9	35	27,1	77,5
	20-35	87	19	21,8	16	18,4	18	20,7	60,9
m+f	35-50	96	11	11,5	38	39,6	32	33,3	84,4
	over 50 years	25	-	-	10	40,0	13	52,0	92,0
	in total	208	30	14,4	64	30,8	63	30,3	75,5

Table 8. F-CE – Prušánky. Frequency of caries.

sex	Age	N	Caries (c.)		Intrav. loss		c.+i.l.		F-CE
			n	%	n	%	n	%	
males	20-35	5	1	20,0	1	20,0	1	20,0	60,0
	35-50	26	1	3,8	12	46,2	9	34,6	84,6
	over 50 years	14	-	-	6	42,8	5	35,7	78,5
	in total	45	2	4,4	19	42,2	15	33,3	79,9
females	20-35	20	4	20,0	4	2,0	3	15,0	55,0
	35-50	37	1	2,7	13	35,1	17	45,9	83,7
	over 50 years	19	-	-	12	63,2	6	31,6	94,8
	in total	76	5	8,2	29	38,2	26	34,2	80,6
m+f	20-35	25	5	20,0	5	20,0	4	16,0	56,0
	35-50	63	2	3,2	25	39,7	26	41,3	90,5
	over 50 years	33	-	-	18	54,5	11	33,3	87,8
	in total	121	7	5,8	48	39,7	41	33,9	79,4

Table 9. F-CE – Josefov.

Sex	Age	N	Caries (c.)		Intrav. loss		c.+i.l.		F-CE
			n	%	n	%	n	%	
male	20-35	2	-	-	1	50,0	-	-	50,0
	35-50	7	-	-	-	-	3	42,9	42,9
	over 50 years	7	-	-	2	28,6	5	71,4	100,0
	in total	16	-	-	3	12,5	8	50,0	68,8
female	20-35	5	2	40,0	-	-	1	20,0	60,0
	35-50	12	1	8,3	2	16,7	5	41,7	66,7
	over 50 years	15	1	6,7	9	60,0	5	33,3	100,0
	in total in total	32	4	12, 5	11	34,4	11	34,4	81,3
m+f	20-35	7	2	28,6	1	14,3	1	14,3	57,2
	35-50	19	1	5,3	2	10,5	8	42,1	57,9
	over 50 years	22	1	4,5	11	50,0	10	45,5	100,0
	in total	48	4	8,3	14	29,2	19	31,7	69,2

Table 10. I-CE – Mikulčice-Kostelisko.

Sex	Age	Preserved	N	c.+i.l.	%	I-CE
male	20-35	teeth	438	17	3,9	7,2
		alveoli	582	19	3,3	
	35-50	teeth	748	29	3,9	13,2
		alveoli	992	92	9,3	
	over 50 years	teeth	180	7	3,9	26,2
		alveoli	318	71	22,3	
	in total	teeth	1366	53	3,9	14,1
		alveoli	1892	182	10,2	
female	20-35	teeth	1168	42	3,6	8,1
		alveoli	1480	66	4,5	
	35-50	teeth	789	43	5,4	22,5
		alveoli	1330	227	17,1	
	over 50 years	teeth	132	19	14,4	45,0
		alveoli	294	90	30,6	
	in total	teeth	2089	104	5,0	16,9
		alveoli	3104	383	11,9	
m+f	20-35	teeth	1606	59	3,7	7,8
		alveoli	2062	85	4,1	
	35-50	teeth	1537	72	4,7	18,4
		alveoli	2322	319	13,7	
	over 50 years	teeth	312	26	8,3	34,6
		alveoli	612	161	26,3	
	in total	teeth	3455	157	4,5	15,8
		alveoli	4996	565	11,3	

Table 11. I-CE – Prušánky.

Sex	Age	Preserved	N	c.+i.l.	%	I-CE
male	20-35	teeth	124	5	3,6	5,8
		alveoli	135	3	2,2	
	35-50	teeth	354	15	4,2	20,5
		alveoli	581	95	16,3	
	over 50 years	teeth	233	11	4,7	20,7
		alveoli	349	56	16,0	
	in total	teeth	711	31	4,3	18,8
		alveoli	1065	154	14,5	
female	20-35	teeth	395	16	4,1	8,5
		alveoli	475	21	4,4	
	35-50	teeth	544	26	4,8	24,5
		alveoli	927	183	19,7	
	over 50 years	teeth	169	15	8,9	55,8
		alveoli	462	225	46,9	
	in total	teeth	1108	57	5,1	28,1
		alveoli	1864	429	23,0	
m+f	20-35	teeth	519	21	4,0	7,9
		alveoli	610	24	3,9	
	35-50	teeth	898	41	4,6	23,0
		alveoli	1508	278	18,4	
	over 50 years	teeth	402	26	6,5	41,1
		alveoli	811	281	34,6	
	in total	teeth	1819	88	4,8	24,7
		alveoli	2929	583	19,9	

Table 12. I-CE – Josefov.

Sex	Age	Preserved	N	c.+i.l.	%	I-CE
male	20-35	teeth	48	-	-	1,8
		alveoli	56	1	1,8	
	35-50	teeth	94	4	4,3	10,3
		alveoli	116	7	6,0	
	over 50 years	teeth	87	8	9,2	32,9
		alveoli	169	40	23,7	
	in total	teeth	229	12	5,2	19,3
		alveoli	341	48	14,1	
female	20-35	teeth	99	4	4,0	5,7
		alveoli	116	2	1,7	
	35-50	teeth	165	5	3,0	13,0
		alveoli	268	27	10,0	
	over 50 years	teeth	147	8	5,4	33,2
		alveoli	335	93	27,8	
	in total	teeth	411	17	4,1	20,8
		alveoli	719	122	16,7	
m+f	20-35	teeth	147	4	2,7	3,9
		alveoli	172	2	1,2	
	35-50	teeth	259	9	3,5	12,4
		alveoli	384	34	8,9	
	over 50 years	teeth	234	16	6,8	33,2
		alveoli	504	133	26,4	
	in total	teeth	640	29	4,5	20,4
		alveoli	1060	169	15,9	

Table 13. I-CE in rich and poor graves – Mikulčice-Kostelisko.

		Preserved	N	c.+i.l.	%	I-CE
male	rich g.	teeth	552	16	2,9	8,8
		alveoli	687	41	5,9	
	poor g.	teeth	814	37	4,5	16,2
		alveoli	1205	141	11,7	
female	rich g.	teeth	686	42	6,1	15,5
		alveoli	915	86	9,4	
	poor g.	teeth	1403	62	4,4	18,0
		alveoli	2189	297	13,6	
m+f	rich g.	teeth	1238	58	4,7	12,6
		alveoli	1602	127	7,9	
	poor g.	teeth	2217	99	4,5	17,4
		alveoli	3394	438	12,9	

Table 14. I-CE in rich and poor graves – Prušánky.

		Preserved	N	c.+ i.l.	%	I-CE
male	rich g.	teeth	101	2	1,9	10,4
		alveoli	142	12	8,5	
	poor g.	teeth	610	29	4,7	20,1
		alveoli	923	142	15,4	
female	rich g.	teeth	442	30	6,8	25,0
		alveoli	660	120	18,2	
	poor g.	teeth	666	27	4,1	29,8
		alveoli	1202	309	25,7	
m+f	rich g.	teeth	543	35	5,9	22,4
		alveoli	802	132	16,5	
	poor g.	teeth	1276	56	4,4	25,6
		alveoli	2125	451	21,2	

Table 15. I-CE in rich and poor graves – Josefov.

		Preserved	N	c.+ i.l.	%	I-CE
male	rich g.	teeth	63	1	1,6	9,0
		alveoli	81	6	7,4	
	poor g.	teeth	166	11	6,6	22,8
		alveoli	260	42	16,2	
female	rich g.	teeth	170	5	2,9	15,9
		alveoli	261	34	13,0	
	poor g.	teeth	241	12	5,0	24,2
		alveoli	458	88	19,2	
m+f	rich g.	teeth	233	6	2,6	14,3
		alveoli	342	40	11,7	
	poor g.	teeth	407	23	5,7	23,8
		alveoli	718	130	18,1	

P. Velemínský/L. Poláček (Hrsg.), Studien zum Burgwall von Mikulčice VIII. Brno 2008, 141-149
Anthropological and epidemiological characterization of Great-Moravian population in connection with the social and economic structure

Linear Enamel Hypoplasia in an Early Medieval Population of Great Moravia

Pavel Trefný[1] – Petr Velemínský[2]

Hypoplastic enamel defects represent the disruption of the enamel matrix secretion during the growth of the tooth crown, which is related to a generalized growth disturbance. The aim of the study was to assess the frequency and timing of the linear enamel hypoplasias (LEH) in two early medieval Great Moravian population samples (9th-10th century A.D.) with different socio-economic statuses. Permanent dentitions of 99 children from the cemeteries in the Mikulčice settlement agglomerations and 64 children from the rural cemeteries in the surrounding area were examined. The age of examined individuals ranged from approximately 5 to 12 years. The timing of LEH was estimated in upper and lower canines by measuring the distance of the LEH from the cemento-enamel junction (CEJ). The LEH-CEJ distance was converted to age using the mean crown heights of the upper and lower canines in the examined samples and the sequence and timing of canine crowns formation in the recent Czech population. We observed no significant differences between the Mikulčice and Mikulčice-Hinterland groups in mean age at LEH formation. The earliest onset of LEH in the pooled sample occurred most commonly at around 3.5 years of life, ranging from 2.0 to 4.75 years. Similar results were observed in individuals with a single LEH. In individuals with two LEH, we obtained a mean age of 3.5 years for the first LEH and 4.2 years for the second LEH.

Key words: Early Middle Age – Great Moravia – linear enamel hypoplasia – timing of linear enamel hypoplasia

1. Introduction

Hypoplastic enamel defects are the manifestations of a defect in teeth mineralisation, more precisely of a defect in the development of enamel (amelogenesis) that leads to the reduction of its strength. The cause of this is a disorder of basal cells responsible for the formation of enamel-ameloblasts. This is thus a case of systemic disruption during the secretory phase of enamel development (e.g. Guatelli-Steinberg 2003). The aetiology of these defects is not completely clear. Most frequently, they are associated with inadequate nutrition or illness suffered during the development of dentition (e.g. Goodman/Rose 1990). Generally, enamel defects associated with systemic metabolic stress, rather than with genetic or traumatic causes, are referred to as "developmental" defects and are indicative of non-specific physiological stress during childhood (e.g. Lovell/Dawson 2003; Boldsen 2005; King/ Humphrey/Hillson 2005). As in contrast to bone tissue enamel is a definitive tissue that cannot be re-modelled, it represents a chronological record of strain and stress endured by a child during the period when the crowns develop (e.g. Skinner/Goodman 1992).

Enamel defects may have various characteristics – most frequently they take the form of continuous/discontinuous horizontal grooves

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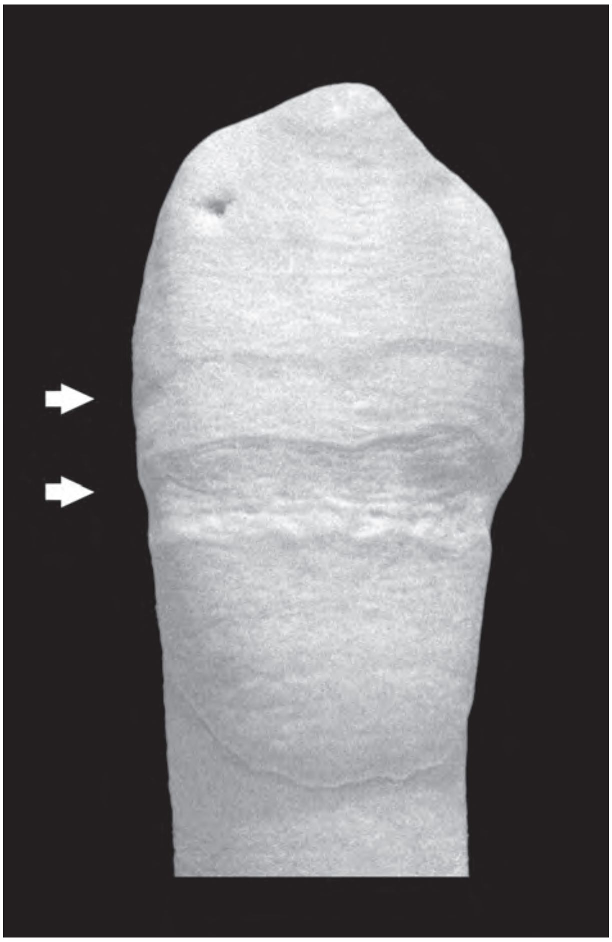

Fig. 1. Linear enamel hypoplasia on the lower left canine. The earliest stress episode can be observed as pit-type hypoplasia. The second and third stress episodes is distinctly manifested as LEH (arrows).

transversing the crown (so-called linear enamel hypoplasia; LEH); on the other hand these defects may involve a single pit or several pits that merely follow the horizontal line or are arranged irregularly (Fig. 1). These may appear on the lingual or facial tooth surface or may circumscribe the tooth. The aetiological and micro-structural differences between the different types of hypoplastic lesions are not well understood (Lovell/Dawson 2003).

All types of teeth may be affected. Individual teeth, though, differ in their sensitivity to stress, which is contingent to the geometry of their crowns. The position of the given tooth within the dental arch also plays an important role. According to research (e.g. Goodman/Rose 1990), the teeth of the anterior section of the arch (incisors, canines) are more susceptible to the development of defects. Posterior teeth have a higher limit threshold for ameloblast disruption (e.g. Goodman/Armelagos 1985; Wright 1997).

The first type of defect listed above, i.e. LEH, is most frequently studied and monitored. This sign is evaluated mainly in the case of incisors and canines of permanent and deciduous dentition. Some researchers prefer the canines of the lower jaw because of their longer developmental period and concurrently their more frequent preservation and relatively inferior abrasion (e.g. Cunha/Umbelino 1995).

In teeth, we may also observe so-called hypo-calcification. This – in contrast to hypoplasia – results in enamel of lower quality due to a systemic insult during the mineralisation phase of enamel development (Lovell/Dawson 2003). This means that hypoplasia and hypo-calcification are linked to a disturbance occurring during a specific phase of enamel development and are associated with a unique process of defect creation.

The location of the LEH on the surface of enamel – its distance from the cemento-enamel junction – and the height of the crown enable one to roughly calculate when it developed, i.e. to determine the age of the child during the period when its organism was "under stress" (e.g. Goodman et al. 1988). This is conditional to knowing the mineralisation chronology of the given crown. Applying this method, which was developed using a recent population, to an archaeological population logically presumes that the dental developmental model in the past was similar to the standards of today. This means that the speed of dental development is consistent among individuals and populations, and that the variability of tooth size does not affect the age-associated determination of hypoplasia (e.g. Lewis/ Roberts 1997). The standards used to determine the period of crown development termination and its height should be the same as those standards employed for determination of age, i.e. for reconstruction of the mortality profile of a studied population. Naturally, dental abrasion of the occlusal dental surfaces that reduces the height of crowns represents the limiting factor for estimation of the period when a hypoplastic defect occurred (Fig. 2).

As shown by previous studies, most defects develop between the 2nd and 4th year of life (e.g. Obertová 2005). This is thus a period when the child in certain societies (hunter-gatherer) abandons a natural diet, is no longer suckled (e.g. Corruccini/Handler/Jakobi 1985; Coppa et al. 1995). The so-called "weaning hypothesis" is based on this event, which may be the cause of defective dental mineralisation. This theory, though, does not correspond to research results, whereby mothers weaned their children in their first year of life, yet the highest frequency of defects occurred in the period between the age of three and four. This "delayed incidence" may be partially explained by the disappearance of maternal antibodies from the child's organism as late as one year after weaning, when the child's own immune system, or rather its acquired adaptive component, is not as yet fully functioning. Nonetheless, it is very probable that environmental conditions also play an important role in the development of hypoplastic defects. This mainly applies to children between the 2nd and 4th year of life (e.g. Goodman/Rose 1990).

Tens, even hundreds of studies have in the past twenty years been devoted to hypoplastic enamel defects. Apart from research studying the chronology of the development of these defects, i.e. the period during which the organism is exposed to stress-related growth-disruptive events (e.g. Goodman et al. 1988; Saunders/Keenleyside 1999) and the difference in their incidence within the dental arch and upper and lower jaws (e.g. Reid/Dean 2000; Lovell/Dawson 2003), there also exist studies that focus on methods and means of evaluation (e.g. Guatelli-Steinberg 2003; Martin et al 2007; Ritzman/Baker/Schwarz 2008). A large group is represented by works attempting to document the frequency of enamel defects in various prehistoric or historical populations (e.g. Palubeckaitë 2001; Jarošová 2005; FitzGerald et al. 2006). Other works have studied the relationship between the frequency of defects and various diseases (e.g. Boldsen 2005). The influence of sex on the incidence of this trait has also been evaluated (e.g. Boldsen 1997; Saunders/Keenleyside 1999). Finally, there also exist studies that investigate whether the incidence of these defects reflects the different social status of individuals (e.g. Cucina/Iscan 1997; Palubeckaitë/Jankauskas/Boldsen 2002; King/Humphrey/Hillson 2005; Boldsen 2007), the geographical (e.g. Wood 1996) or chronological (e.g. Cucina 2002) distinctness of population groups. Verification of the effect of social status on the incidence of enamel defects was also one of the aims of our study.

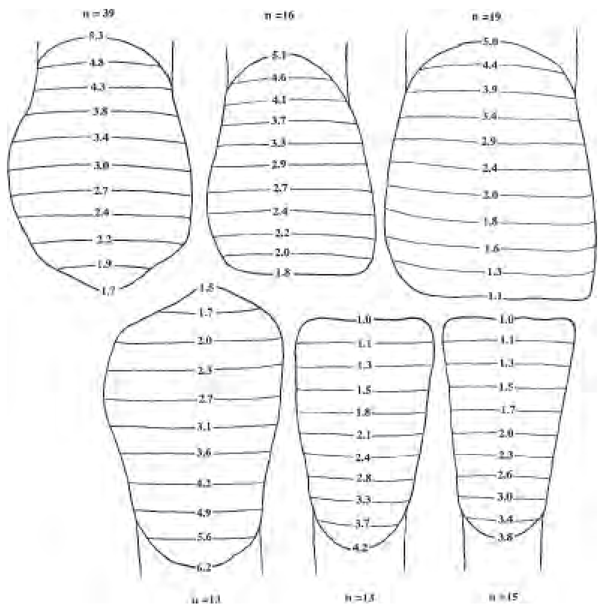

Fig. 2. Timing of anterior tooth growth. The right anterior quadrant of the mouth is depicted as when viewed clinically by an observer. Each height of each type of tooth is divided into 10 equally spaced zones. The age when enamel appears at the incisal edge is considered to be coincident with the completion of cuspal enamel. The age at completion of each zone of surface enamel formation is shown in years to one decimal place (Reid/Dean 2000).

The aim of the study was to assess the frequency and timing of linear enamel hypoplasias (LEH) in two early medieval Great Moravian population samples (9th-10th century A.D.) with different socio-economic status.

2. Material

The permanent dentition sample consisted of the dental remains of 163 individuals from the following archaeological sites:

The Settlement Agglomeration of Mikulčice (M group), presumed to be a centre of the Great Moravian Empire in the 9th-10th century A.D. Skeletal remains of about two thousand individuals have been excavated here so far. LEH were scored in 67 individuals from the castle area and in 32 individuals from the sub-castle area. Based on the archaeological excavations, it can be concluded that members of the higher social classes of the Great Moravian empire (warriors, priests) were buried here.

The Rural Hinterland of Mikulčice (MH group) is represented by two cemeteries in the area surrounding the Mikulčice settlement – Prušánky and Josefov. LEH were scored in 41 individuals from the Prušánky I cemetery and in 23 individuals from the Josefov cemetery. In contrast to the Mikulčice site, the poor equipment of graves indicated the rural character of this population.

Only teeth free of attrition and abrasion, with completed crown development and sufficiently well preserved to allow examination of the crown surface were included. The age of the examined individuals ranged from approximately five to 12 years.

3. Methods

The presence or absence of LEH was recorded by visual examination of the enamel surface under an oblique spotlight. An individual was regarded to be free of LEH if at least two anterior permanent teeth from that individual were available for examination and none of them exhibited LEH. If at least two anterior permanent teeth exhibited LEH that could be matched chronologically, the individual was considered to be LEH-positive. Defects not matched chronologically in at least two frontal teeth were not considered to be LEH.

In the upper and lower canines, the distance of the occlusal border of the LEH from the cemento-enamel junction (CEJ) was measured using a thin-point digital Mitutoyo sliding calliper. Mean crown heights of the upper and lower canines were also determined in unworn, largely unerupted specimens. The sequence of the upper and lower canine crown formation in the examined sample was determined by matching the unerupted canine crowns of the given individual according to the LEH. In most cases, lower canines exhibited a slightly earlier onset and later completion of crown development than upper canines. The age at LEH formation was then estimated using the mean crown heights of the upper and lower canines in the examined samples and the timing of canine crown formation as given in three different developmental charts (Table 1).

There is only one mineralisation chart available for the recent Czech population (Handzel 1996). In this study, the timing of crown development was determined using the position of enamel hypoplasia on the crown surface and the corresponding periods of tetracycline usage stated in the patient's medical record. Probably the most recent developmental chart, that of Reid/Dean (2000), was developed and based on the histological examination of extracted unworn anterior teeth. This chart was modified according to the sequence of upper and lower canine crown formation in the studied sample. To avoid systematic error in the mineralisation standard, we tested the sequence of upper and lower canine crown formation using three developmental charts.

4. Results

The incidence and frequency of LEH are given in Table 2. The prevalence of LEH was higher in the M group: 76.8% individuals had one or more linear enamel hypoplasia. The chi-square test showed a significant difference between the two groups ($p<0.05$).

Both the M and MH groups were characterised by a relatively low number of defects per individual. The majority of individuals had one or two LEH, five individuals exhibited three LEH and four LEH were observed only in one individual.

Table 1. Developmental charts used for estimating age at LEH formation.

		Developmental Age		Regression Equations
		at cusp	at CEJ	
Reid and Dean (2000)	Upper canine	1.7	5.3	-0.336x + 5.3
	Lower canine	1.5	6.2	-0.420x + 6.2
Reid and Dean (2000) modified	Upper canine	1.7	5.3	-0.336x + 5.3
	Lower canine	1.5	5.5	-0.357x + 5.5
Handzel (1996)	Upper canine	0.9	3.8	-0.271x + 3.8
	Lower canine	0.6	4.2	-0.322x + 4.2

Table 2. Incidence and frequency of LEH in the examined samples.

	Individuals Affected	Individuals Examined	%	Chi-square	p
Mikulčice settlement	76	99	76.8		
Rural hinterland	40	64	62.5	3.86	0.049
Total	116	163	71.2		

Table 3. Mean crown heights of the upper and lower canines in the examined sample.

	Crown height	SD	N	Range
Upper canine	10.80	1.05	57	8.50 - 12.89
Lower canine	11.21	0.88	52	9.75 - 13.00

Table 4. Mean age at LEH formation in individuals with single LEH in both upper and lower canines.
* indicates 5% level of significance

		Mean Age	SD	N	Diff.	Range	t
Reid and Dean (2000)	Upper canine	3.54	0.77				
	Lower canine	3.85	0.86	18	-0.31	-0.69 - 0.07	-7.09 *
Reid and Dean (2000) modified	Upper canine	3.54	0.77				
	Lower canine	3.55	0.75	18	-0.01	-0.29 - 0.28	-0.34
Handzel (1996)	Upper canine	2.38	0.62				
	Lower canine	2.40	0.66	18	-0.02	-0.29 - 0.26	-0.57

Table 5. Mean age at LEH formation in individuals with single and two LEH, mean age at the earliest LEH formation.

		Mean Age	SD	N	Range
Subjects with single LEH		3.77	0.67	38	2.00 - 4.75
Subjects with two LEH	first LEH	3.48	0.50	21	2.54 - 4.34
	second LEH	4.16	0.43	21	3.46 - 5.01
Earliest LEH observed		3.64	0.64	59	2.00 - 4.75

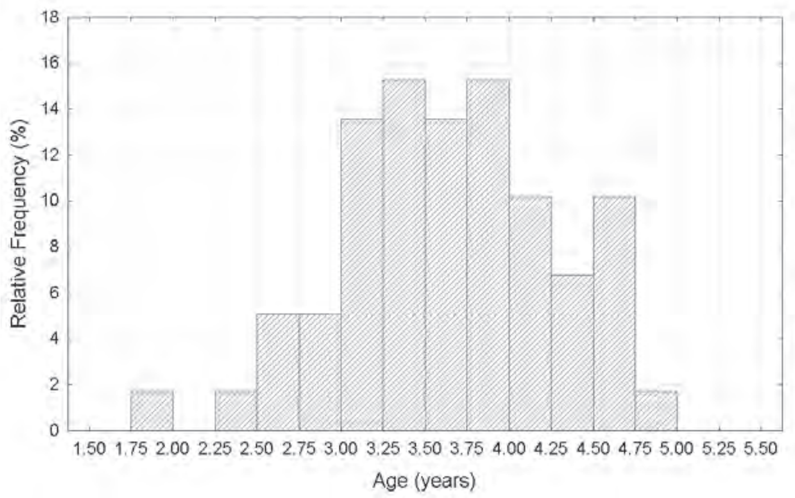

Fig. 3. Chronological distribution of the earliest LEH in each individual (individuals with one or more LEH included).

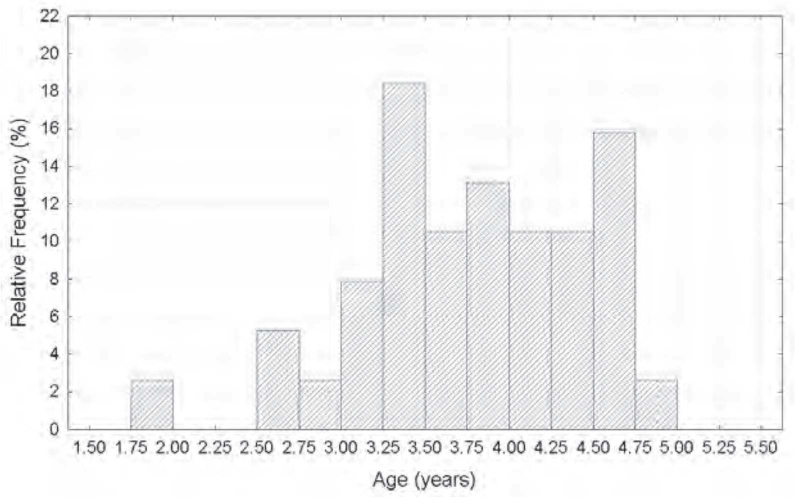

Fig. 4. Chronological distribution of LEH in individuals with single LEH.

There were no significant differences in mean crown heights between the two groups and therefore, the data was pooled (Table 3). In individuals whose upper and lower canines exhibited one chronologically matched LEH, Student's t-test was used to verify the timing of the upper and lower canine crown formation as given in the three mineralisation charts (Table 4). Mean ages at LEH formation in upper and lower canines should ideally be identical.

The J. Handzel mineralisation chart (1996) performed well in the test. We obtained identical mean ages at LEH formation in upper and lower canines. However, this chart gave extremely low age values for cuspal enamel completion and also rather low age values for crown completion as compared to other mineralisation schemes. Therefore, it has been omitted from this study.

Using the Reid/Dean developmental chart (2000), we found that the timing of upper and lower canine crown formation did not match the sequence of upper and lower canine development observed in the examined sample. The mean age at LEH formation in lower canines was about 0.3 years greater than in the case of upper canines. Therefore, this mineralisation chart was modified according to the sequence of upper and lower canine crown formation in the studied sample. Completion of lower canine crown formation was shifted from 6.2 years to 5.5 years. Using this modified chart, we obtained identical mean ages at LEH formation in upper and lower canines.

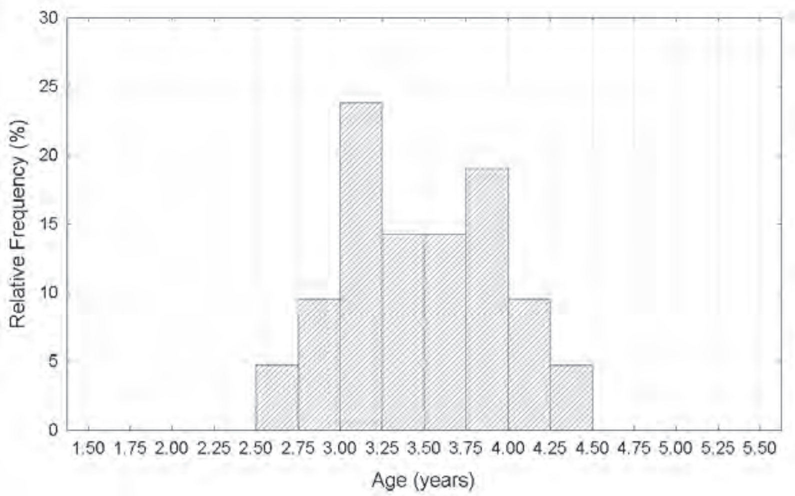

Fig. 5a. Chronological distribution of LEH in individuals with two LEH (first LEH).

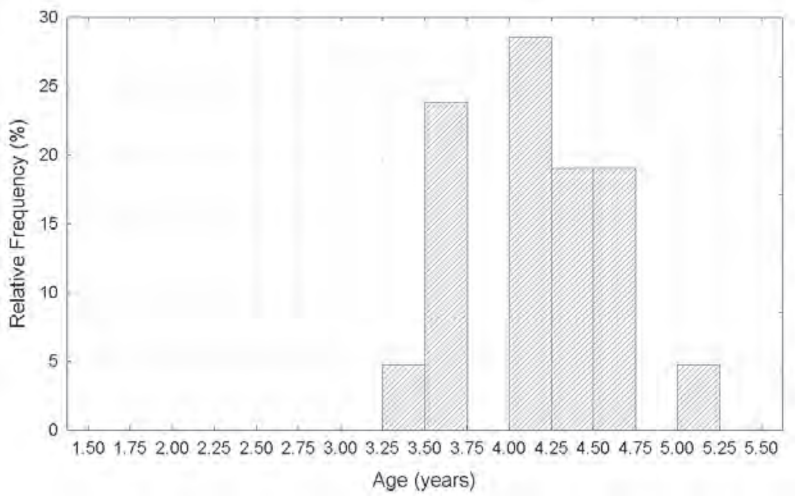

Fig. 5b. Chronological distribution of LEH in individuals with two LEH (second LEH).

We observed no significant differences between the M and MH groups in mean age at LEH formation, therefore, the data was pooled (Table 5). The earliest onset of LEH in the pooled sample occurred most commonly at around 3.5 years of life, ranging from 2.0 to 4.75 years (Fig. 3). Similar results were observed in individuals with a single LEH (Fig. 4). In individuals with two LEH, we obtained a mean age of 3.5 years for the first LEH and 4.2 years for the second LEH (Fig. 5).

5. Discussion

The prevalence of LEH in the M and MH groups was found to be comparable to the frequencies reported in medieval samples. It could be argued that rigorous criteria for selection of teeth biased the sample towards younger individuals, resulting in overestimation of the frequency of LEH. But we presume that only teeth free of attrition and abrasion can provide reliable evidence of stressful events. Subtle LEH involving only few perikymata cannot be easily identified in older individuals due to the rapid abrasion of the enamel surface in prehistoric populations. Another issue is the frequent occurrence of calculus and adherent deposits that cover the cervical enamel on the buccal surfaces of frontal teeth. This can result in underestimation of LEH prevalence.

Although the severity of LEH has not been scored yet, it can be concluded that predominantly mild to moderate degrees of LEH occurred in both groups. Differences between the M and MH group in the prevalence of LEH are surprising. Previous anthropological studies confirmed that the higher social classes of the Great Moravian Empire (i.e. subjects with better living conditions) were buried at Mikulčice-castle. On the contrary, the cemeteries of the sub-castle and the hinterland of Mikulčice were probably the burial sites of the poorer social classes. Josefov, for instance, was very likely to have been the cemetery of the rural population only. Therefore, we presume that the MH group experienced more stress during childhood.

Since many studies of historical and contemporary populations have confirmed a relationship between poor nutrition and a higher incidence of LEH, we would expect the rural MH group to show a higher frequency of LEH. But the opposite is true. The well-situated M population exhibited a significantly higher frequency of LEH. Palubeckaitė/Jankauskas/Boldsen (2002) observed a similar situation in their analysis of LEH in Danish and Lithuanian late medieval samples.

Using multiple teeth (typically the upper first incisor and lower canine) to obtain the age at LEH formation, some studies have shown two different peak ages of stress in a single population. Although such differences could most likely be attributed to a systematic error in the mineralisation standard, some authors have suggested a different susceptibility of individual teeth to stress.

There is no reason to assume that one episode of stress will produce LEH at two different ages. But it is also clear that different inter- and intradental susceptibilities to stress exist in human dentition. For instance, in two teeth developing at the same time, one stressful event can perceptibly manifest as LEH in one tooth only. In the second tooth, LEH can be much less obvious or not present at all. In the studied sample, we observed such differences in both adjacent and opposite teeth.

It has been well documented that a considerable part of the upper and lower canine crown formation is not expressed on the crown surface. A combination of lower first incisors and canines is often used to obtain an estimation of the age at LEH formation, as this covers the period from approximately 1 to 5.5 years of life. However, there still remain two main difficulties associated with the use of multiple teeth: correct crown formation timing of the teeth studied and the nonlinear nature of dental growth.

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Anthropological and epidemiological characterization of Great-Moravian population in connection with the social and economic structure

Trace Elements in Human Skeletal Material from the Great Moravian Burial Site at Mikulčice-Kostelisko

Václav Smrčka[1] – Petr Velemínský[2] – Martin Mihaljevič[3] – Jarmila Zocová[4]

Differences in the inorganic bone content of trace elements between a group of adult males and females as well as between social groups with different grave equipment were discovered at the Slavic burial site of Mikulčice-Kostelisko in the sub-castle. Significant sexual dimorphisms were shown in the case of the elements Ca, Sr, Zn, Pb, Mg, Cu and Ba. For example, a higher content of zinc (406.1 ±586 µg Zn/g of bone) was observed in the bones of males (N13) compared to those of females (N15) (161±53 µg Zn/g of bone) (p< 0.02). The diet of males contained a higher proportion of proteins, most probably originating from a meat-based diet. When using the Spearman's rank correlation coefficient to test femurs, it was found that concentration of certain elements decrease with age, significantly so in males – in the case of Yb (p= 0.008), even when correlated to calcium, while in the case of Ni, Y, Dy, Er, Tm, Lu, this association is borderline significant p= 0.053. The significance of multi-elemental analysis for the reconstruction of diet lies in the possibility of comparing elemental relationships that are not obvious in small groups of analysed elements.

Key words: trace elements – human skeletal remains – Great Moravian population – social status – diet – environment

1. Introduction

The improvement of analytical methods in the past decades has made it possible to employ trace elements found in bone remains for the reconstruction of diet. The human diet is converted into the language of elements: not the separate components of the diet itself, but rather the sources of elements are determined. By determining the element whose movement within the food-chain is known, it is possible to determine whether the dietary regimen several years before death was based on a vegetal diet or on animal proteins.

Measurement of strontium concentrations in human bones became the basis for the method that led to the evaluation of the contribution of plant components and animal proteins to diet (Brown 1973, 1974; Schoeninger 1979; Sillen 1981; Price/Kavanagh 1982; Blakely 1989; Burton/Price 1999).

The metabolic similarities between strontium and calcium (incorporation into the bone, occupation of the same area within the apatite matrix, as well as the small fluctuations of calcium concentrations among living individuals) inspired some authors to use a strontium-calcium index as a gauge for the amount of strontium ingested in food (Comar/Scott-Russell/Wasserman 1957; Price/Kavanagh 1982; Sillen/Kavanagh 1982). Another group assumed that the fluctuation of bone calcium

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is negligible and used strontium for the reconstruction separately (Toots/Voohries 1965; Brown 1974; Schoeninger 1979; Lambert/Szpunar/Buikstra 1979).

Like calcium, Sr^{90} also moves within the food-chain and is easily absorbed by plants. It is accessible to grazing animals on the surface of leaves. When it is absorbed into the leaves, it mixes in various proportions with plant calcium. In man, it is deposited and retained in bones and transported into milk and the developing foetus. Nuclear explosions endanger the biosphere with the presence of Sr^{90}. It is a paradox that this originally purely military research, aimed at the destruction of the human population, also provided information that gave us the impulse to understand life in the past.

Comparison of Sr and barium concentrations in carnivores and herbivores showed that Sr is much less sensitive to dietary variations than is Ba. Barium is concentrated on the bone surface like manganese (Lambert et al. 1984). Parker/Toots (1980) documented a certain degree of contamination. Barium is thus excellent for distinguishing the type of diet. However, archaeological results are probably endangered by diagenetic effects.

Zn seems to be exempt from diagenetic processes, at least in the case of burial grounds in non-acid soils, several thousands years old. Whilst Sr decreases in the succession from herbivores 400-500 ppm, omnivores 150-400 ppm, to carnivores 100-300 ppm, Zn concentrations increase in the same series from 90-150, 120-220, 175-250 ppm (Lambert et al. 1984; Reinhold et al. 1973; Reinhold 1975). Relatively high values of zinc are found in meat, and high concentrations of Zn can also be found in nuts and molluscs (Gilbert 1977).

Lead analysis provides pathological information that remains useful even in an anthropological context (Wittmers/Alich/Aufderheide 1981; Aufderheide et al. 1981, 1985; Aufderheide 1989).

Our objective was to reconstruct diet based on the analysis of elements contained in human skeletal remains. We did not determine individual components of the diet, but rather the sources of elements, which predominated in the given population.

The only elements that can be used for diet reconstruction are those whose concentration is minimally affected by the influence of the surrounding environment, or those whose changes in concentration can be expressed mathematically. For this purpose, we chose zinc and strontium, as their concentrations in a buried skeleton are influenced only minimally by soil composition (Smrčka 2005; Sandford 1992). The chemistry of the enamel reflects that obtained through the diet of early childhood and thus has the potential to inform about changes in childhood diet (e.g. nursing and weaning). Also, because enamel retains elements of the diet during early childhood, it is most valuable for the study of human mobility and provenience. The amounts of strontium, barium and lead can vary geographically and thus may be potentially used in enamel to distinguish places of human origin (Burton 2008).

Multi-elemental chemical analysis was used to study skeletons from the Great Moravian burial site at Mikulčice-Kostelisko. The aim of this work was to determine the content of elements in the skeletons of the adult human population in order to reconstruct the diet and learn about the environment inhabited by the people from Mikulčice and its surroundings.

2. Materials

Samples from the proximal right femurs opposite the small trochanter were taken for the anthropological determination of age and sex from the twenty eight human adult skeletons (aged between 20-50 years) from the Slavic burial site at Mikulčice-Kostelisko in the sub-castle (Velemínský et al. 2005), deposited in the National Museum (Smrčka 2005).

The analysed sample of human skeletons from Mikulčice-Kostelisko included 14 males and 14 females (see Table 1).

Bone fragments were rid of any earth remnants using a PVC brush. They were then washed in deionised water and soaked in formic acid in order

Table 1. The basic informations about evaluated skeletons from burial ground Mikulčice-Kostelisko.

Grave No.	Invent.No.	Sex	Age I	Age II	Grave Goods	
					Stloukal (1970)	Hrubý (1955)
1573	16770	male	adultus (20-25 yrs)	20-35 years	2	5
1576	16773	female	adultus (30-40 yrs)	35-50 years	2	5
1600	16794	? (female ?)	adultus (30-40 yrs)	35-50 years	2	5
1605	16799	female ?	adultus (20-25 yrs)	20-35 years	2	5
1648	16831	female	adultus (20-30 yrs)	20-35 years	1	4
1725	16941	female	adultus (30-40 yrs)	35-50 years	2	5
1725	16941	female	adultus (30-40 yrs)	35-50 years	1	2
1742	16889	? (female ?)	adultus (20-25 yrs)	20-35 years	1	2
1792	16917	male	adultus (30-40 yrs)	35-50 years	2	4
1794	17129	male	juvenis (17-20 yrs)	17-20 years	2	5
1797	16918	? (female ?)	adultus (30-40 yrs)	35-50 years	2	4
1809	16923	male	maturus (40-50 yrs)	35-50 years	1	2
1820	17136	female	adultus (30-40 yrs)	20-35 years	2	4
1832	16939	female	adultus (20-30 yrs)	20-35 years	2	5
1837	17143	male	adultus (30-40 yrs)	35-50 years	2	4
1860	16964	male	maturus (40-50 yrs)	35-50 years	2	4
1861	16951	male	adultus (20-30 let)	20-35 years	2	4
1862	17152	? (male ?)	adultus (20-30 yrs)	20-35 years	2	5
1907	16997	? (male ?)	adultus (30-40 yrs)	20-35 years	2	4
1908	16998	male	maturus (40-50 yrs)	35-50 years	1	2
1912	17167	male ?	maturus (40-50 yrs)	35-50 years	1	2
1924	17173	female	maturus (40-50 yrs)	35-50 years	2	5
1938	17181	female ?	maturus (40-50 yrs)	35-50 years	2	4
1945	17185	male	adultus (30-40 yrs)	35-50 years	2	5
1973	17034	female	maturus (40-60 yrs)	up 50 years	1	4
1975	17031	male	maturus (50-60 yrs)	up 50 years	1	2
1998	17010	female	adultus (20-30 yrs)	20-35 years	2	5
2005	17003	male	maturus (40-50 yrs)	35-50 years	2	5
1777A	16902	female	adultus (30-40 yrs)	35-50 years	1	3

to remove the diagenetically affected sections. Following thorough rinsing with deionised water and subsequent drying, the bone samples were coated in an agate dish for analytical precision.

Samples of soil from the given location were taken concomitantly with the bone samples. The soils were sifted using a sieve with 2 mm large apertures (mesh) and then dried in the laboratory until a constant weight was attained. Once dried, the soils were homogenised in an agate mill to an analytical precision.

3. Methods

3.1 Chemical analysis

Exactly about 0.2 g of the bone sample was weighed out and transferred into a 50 ml graduated glass and 5 ml of concentrated HNO_3 was poured over it. The sample was then slowly dissolved by careful warming on a heater plate, at approx. 80° C. Upon cooling, deionised water was added to each graduated glass. A blind test was prepared for every series of ten samples. The overall mineralisation of the soil was conducted as follows. Exactly around 0.2 g of the soil placed in a platinum dish was annealed in an oven (Linn, FRG) up to a temperature of 450° C. Upon cooling, 10 ml of concentrated HF and 0.5 ml of concentrated $HClO_4$ were poured over the sample, which was then defumed in a fume chamber into moist residue. Subsequently, the residue in the dish was dissolved in water and with the addition of 2 ml HNO_3 transferred to a 100 ml graduated glass. Merck brand acids and deionised water from MilliQPlus (Millipore, USA) were used to prepare the solutions.

The contents of Ca, Mg, K, Fe, Na in the mineralised samples was determined using flame atomic absorption spectrometry (Spectra AA 200 HT, Varian Australia) under the conditions recommended by the manufacturer.

The contents of V, Cr, Co, Ni, As, Y, Cd, Ba, Pb, U, La, Ce, Pr, Nd, Sm, Eu, Gd, Tb, Dy, Ho, Er, Tm, Yb and Lu in the mineralised samples was determined using mass spectrometry with induction-bound plasma (PQ 3, VG Elemental, Great Britain) under the following conditions: energy output ICP 1350 W, measuring mode "peak jump", duration of measurement 3 x 50 s, ^{115}In optimised parameters of ionic optics, gas flow volume 13.5 l/min cooling, 0.7 l/min auxiliary, 0.65 l/min nebuliser, internal standards In, Re, Sc.

The Asrasol brand solution (Analytika, Czech Republic) was used to calibrate both measurements.

The method was tested in certified reference bone material, NIST SRM 1486 .

3.2 Statistical analysis

Twenty-eight samples from human adult skeletons were used for statistical analysis.

Trace elements following the analysis of samples from 28 human skeletons were statistically tested from the aspect of sexual dimorphisms in groups of males (N=14) and females (N=14) and in all groups together.

Furthermore, testing was conducted in groups of garnitures according to grave equipment, in accordance with Stloukal's classification (1-rich grave equipment, 2-poor grave equipment) (Stloukal 1970). Division according to V. Hrubý (1955) was not conducted in view of the small number of elements within the groups.

The Statistika programs, version 7.0 from Stat Soft were used in the evaluation.

4. Results

4.1 Sexual dimorphisms in the content of trace elements in human skeletons

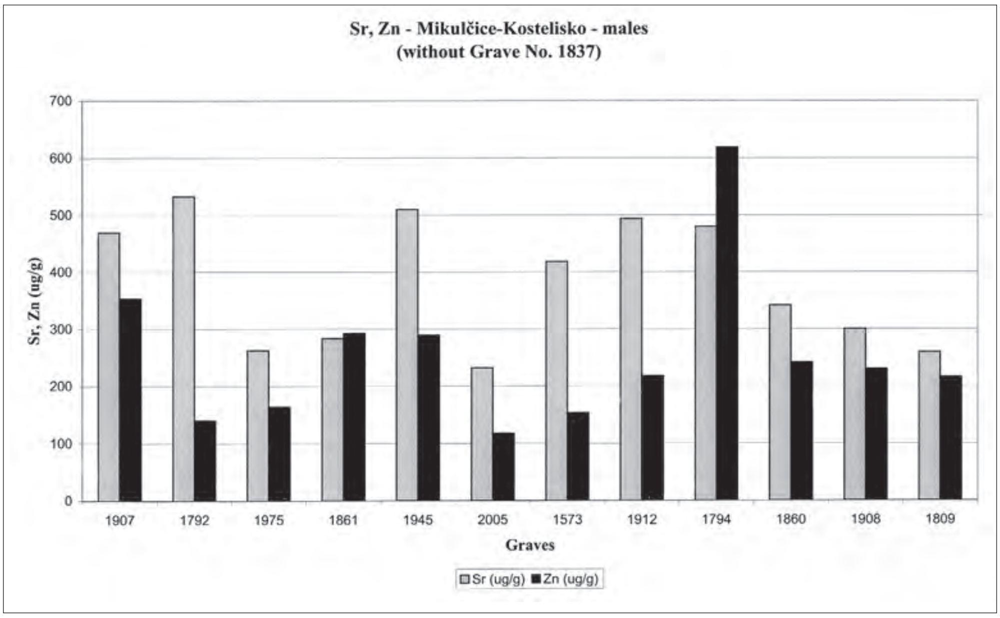
An overview of the content of elements in the skeletons from the burial site at Mikulčice-Kostelisko for which statistically significant differences were recorded is detailed in Table 2.

Differences between the groups of adult males and females with both rich ("Stloukal 1") and poor ("Stloukal 2") grave equipment were found in the bone contents of the elements Ca, Sr, Zn, Pb, Mg, Cu (see Table 2a). An analysis for every statistically significant element was conducted on the basis of testing of the elements content in the skeletons using the variance analysis according to sex (see Table 2b, 2c).

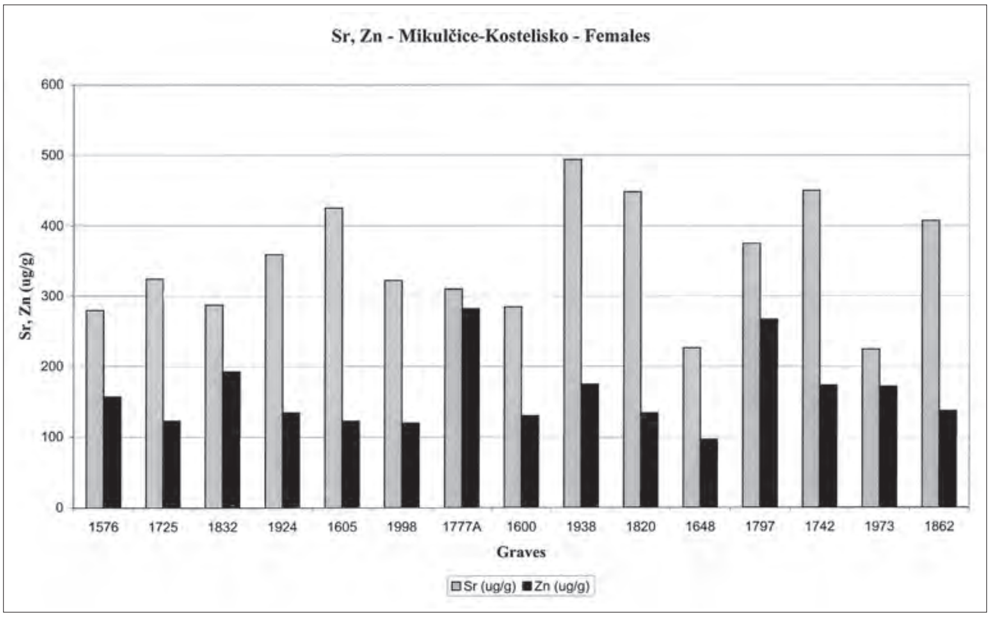
Ca contents in the bones of females (N=15) (294 313.3 ± 31 643 µg Ca/g of bone) were higher than in those of males (N=13) (278 661 ± 312 33 µg Ca/g of bone). Even in the bones of eleven females with poor grave equipment (304255 ± 23611 µg), the Ca contents were higher than in the case of the nine males (287694 ± 26811 µg) (p<0,044) with poor grave equipment. The soil from the burial site contained 6825 µg Ca/g of soil.

Sr contents in the bones of males (N=13) (390 ± 112 µg Sr/g of bone) were higher than in those of females (N=15) (348 ± 83 µg Sr/g of bone). Even in the bones of nine males with poor grave equipment (418 ± 107 µg/g), the Sr contents were higher than in the case of the eleven females (364 ± 72 µg/g) also with poor equipment.

The Sr contents in the bones of four males with rich grave equipment (329 ± 111 µg/g) were higher than in the case of the four females also with rich equipment (302 ± 106 µg/g).



Graph 1a. Strontium and zinc in males from the Mikulčice-Kostelisko burial site (when excluding the contents of grave 1837).



Graph 1b. Strontium and zinc in females from the Mukulčice-Kostelisko burial site.

The soil from the burial site contained 94 µg Sr/g soil.

Zn contents in the bones of males (N=13) were higher (406.1 ± 586 µg Zn/g of bone) than in those of females (N=15) (161 ± 53 µg Zn/g of bone) ($p<0.02$). Even in the bones of eight males with poor grave equipment (494 ± 674 µg/g), the Zn contents were higher than in the case of eleven females (154 ± 44µg) ($p=0.048$) also with poor equipment.

The soil from the burial site contained 29 µg Zn/g of soil.

Pb contents in the bones of males (N=13) (2.22 ± 5.31 µg Pb/g of bone) were higher than in those of females (N=15) (0.25 ± 0.23 µg Pb/g of bone). In nine males with poor grave equipment, the bone content of lead (2.91 ± 6.36 µg/g) was higher than in the case of the eleven females (0.27 ± 0.27 µg/g) ($p<0.001$) also with poor equipment.

The Pb content in the bones of four males with rich grave equipment (0.65 ± 0.5 µg/g) was also higher than in the case of four females with rich equipment (0.18 ± 0.06 µg/g) ($p<0.09$). The soil from the burial site contained 10.8 µg Pb/g of soil.

Mg contents in the bones of females (N=15) (1029.7 ± 165 µg Mg/g of bone) were higher than in those of males (N=13) (933.8 ± 160.64 µg Mg/g of bone). Even in the bones of eleven females with poor grave equipment (1046 ± 109 µg/g), the magnesium contents were higher than in the case of nine males (967 ± 149 µg/g) (p=0.09) with poor equipment. The soil from the burial site contained 1614 µg Mg/g of soil.

Cu contents in the bones of males (N=13) (5.4 ± 2.42 µg Cu/g of bone) were higher than in those of females (N=15) (4.2 ± 2.02 µg Cu/g of bone). Even in four males with rich grave equipment (5.23 ± 2.12 µg Cu/g of bone), the copper contents were higher than in the case of four females (3.25 ± 2.01 µg/g) (p=0.083) also with rich equipment. The soil from the burial site contained 14.30 µg Cu/g of soil.

Ba contents in the bones of males (N=13) (57.1 ± 27.57 µg Ba/g of bone) were higher than in those of females (N=15) (4.2 ± 2.02 µg Ba/g of bone). Even in nine males with poor grave equipment (67.17 ± 26.57 µg/g), the Ba contents were higher than in the case of eleven females (43.4 ± 17.59) (p=0.028) also with poor equipment. The soil from the burial site contained 370 µg Ba/g of soil.

4.2 Bone contents of trace elements in 28 individuals from the burial site at Mikulčice and association with age

Significant differences (p<0.008 up to 0.053) in the bone content were discovered in the case of the following elements: Ni, Y, Dy, Er, Tm,Yb, Lu (Table 3). When testing femurs using the Spearman's rank correlation coefficient, we found a decrease in the content of elements in association with age. This decrement was significant in males – in the case of Yb (p=0.008), even when correlated to calcium. In the case of Ni, Y, Dy, Er, Tm, Lu, this association was borderline significant p=0.053.

4.3 Social relations deduced from the different bone contents of elements in the case of graves with rich and poor equipment at the burial site

We took the grave equipment as the basis for our evaluation of social relations. We took into account the classification according to Stloukal (1970) (l = rich graves, 2 = poor graves), as well as that of Hrubý (1955) (1, 2 = rich graves, 3 to 5 = poor graves).

Five (of eight) males with poor grave equipment (grave 1794, grave 1907, grave 1860, grave 1861, grave 1945) had a higher zinc content than did the four wealthy males (207 ± 29 µg/g) (grave 1809, grave 908, grave 1912, grave 1975). A content of over 300 µg Zn/g of bone was found in graves 1907 and 1794. Males had the highest content of zinc (Graph 1a).

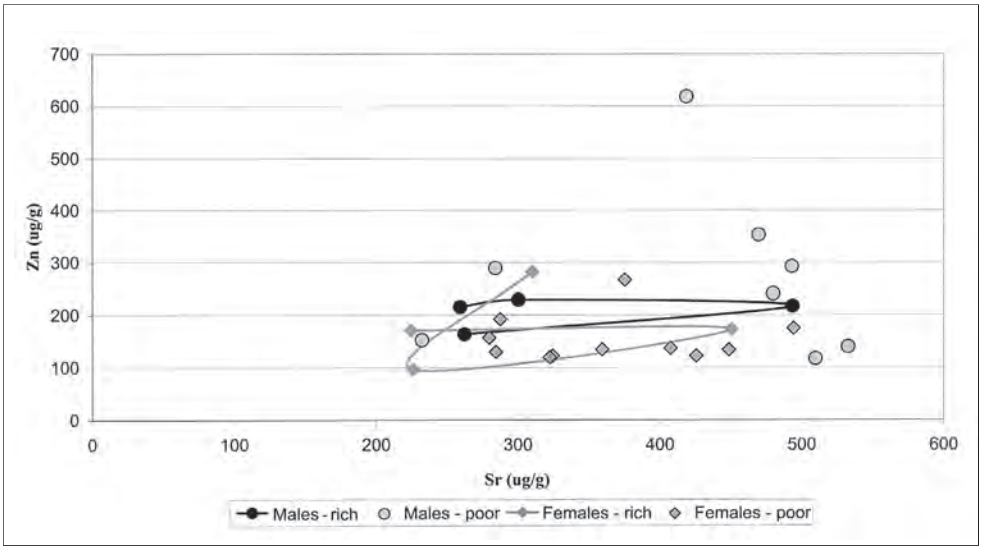
Rich males had more zinc than rich females. Only one female, rich /1/ according to Stloukal and poor according to Hrubý (grade 3) (1777A), had more zinc than rich males (Graph 2a, 2b).

Tables 4a, 4b summarise the statistical results of the double sorting analysis, which tested concurrently the hypothesis regarding the influence of sex and grave paraphernalia. Significant results were acquired for zinc, lead and barium.

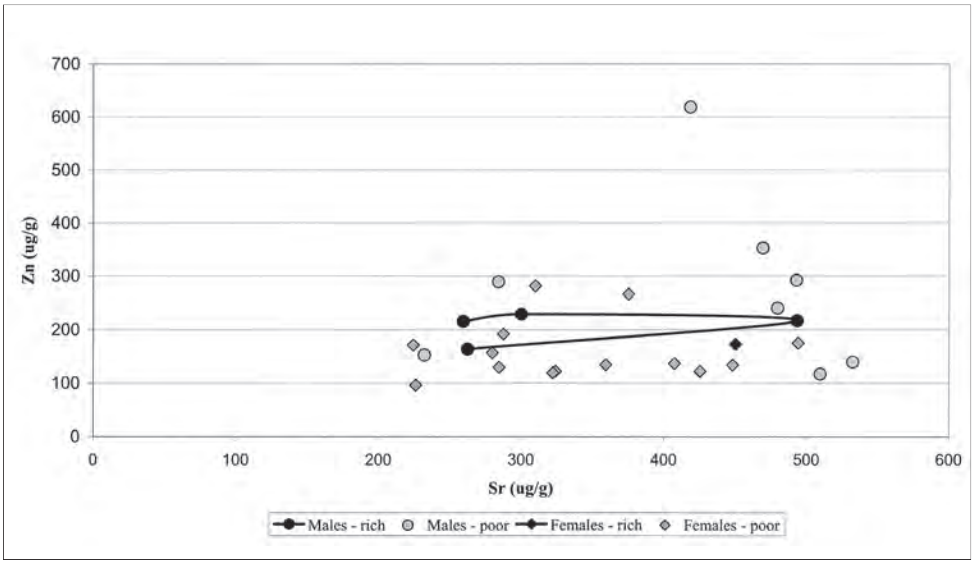
5. Discussion

The allocation of trace elements into distribution groups of the human population (males and females) at the Slavic burial site allowed us to study the content of individual elements in the skeletal remains of these groups, as well as the relationships between these two groups.

In the human population of Slavs, the bone content of the elements Zn, Pb, Mn, Fe, Cu, Mg, Cr, Co, Ni, As, Y, La, Ce, Pr, Sm, Eu, Gd, Tb, Dy, Ho, Er, Tm, Yb, Lu and U follows the age growth curve. In this case, these elements were analysed in the adult population of males and females. They included metal elements predominating in the proximal and distal sections of bones, of which many play a role during growth in the form of metaloenzymes (Smrčka 2005).



Graph 2a. Strontium and zinc in the skeletons from the Mikulčice-Kostelisko burial site, in relation to sex and grave equipment according to Stloukal (without grave 1837).



Graph 2b. Strontium and zinc in the skeletons from the Mikulčice-Kostelisko burial site, in relation to sex and grave equipment according to Hrubý (without grave 1837).

In the femurs of Slavs from the Mikulčice burial site at Kostelisko, testing using Spearman's rank correlation coefficient uncovered a decrease of certain elements with age, namely in males. We recorded a significant decrease in males of Yb (p=0.008) in correlation with calcium. In the case of Ni, Y, Dy, Er, Tm, Lu, this correlation was borderline significant p=0.053.

The decrease of the essential element, nickel whose daily-recommended dose is 25-35 µg (Nielsen 2000) was quite notable. Increased losses may occur in persons with increased intake of fats, sugars and diary products (Underwood 1977).

The diet of adult individuals from the Mikulčice -Kostelisko burial site differed, depending on sex and wealth.

Higher contents of zinc (406.1 ± 586 µg Zn/g of bone) were discovered in the bones of males (N=13) compared to those of females (N=15) (161 ± 53 µg Zn/g of bone) ($p \leq 0.02$). The diet of males consisted of a higher proportion of proteins, probably from a meat-based diet. The relatively high values of bone zinc originate from a meat-based diet, nuts and molluscs (Gilbert 1977, 1985).

The diet of females consisted predominantly of a vegetal component. All females had more strontium than zinc. None of the females had strontium levels over 500 µg and none of the females had zinc levels over 300 µg. One woman (grave 1648) had a zinc content of less than 100µg, and such a value was not recorded in any man (Graph 1b).

The female from grave 1973 (over 50 years) with rich grave equipment and the male from grave 1809 (35-50 years) both had an increased bone content of sodium, which could confirm an increased proportion of a millet-based diet (Boardman 1975).

According to historical reports, the Slavs took a liking to millet. It was an expensive cereal, though. Millet mash was often a festive or prestigious meal (Beranová 2005).

6. Conclusion

The bone content of adult individuals from the Great Moravian burial site at Mikulčice-Kostelisko differed, depending on sex and wealth. Significant sexual dimorphisms were shown in the case of the elements Ca, Sr, Zn, Pb, Mg, Cu and Ba. For example, higher contents of zinc (406.1 ± 586 μg Zn/g of bone) were found in the bones of males (N=13) compared to those of females ($p<0.02$). The diet of males consisted of a higher proportion of proteins, probably from a meat-based diet.

Testing of femurs using the Spearman's rank correlation coefficient showed a decrease in element of content with age, significantly so in males – in the case of Yb ($p=0.008$), even when correlated to calcium. In the case of Ni, Y, Dy, Er, Tm, Lu, this association was borderline significant $p=0.053$.

The importance of multi-elemental analysis in the reconstruction of diet lies in the possibility of comparing elemental relations that are not obvious in the case of small groups of analysed elements.

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Table 2. Contents of stable elements in the skeletons from the Mikulčice-Kostelisko burial site.

	Males						Females					
	Means	N	Minimum	Maximum	Std. Dev.	Median	Means	N	Minimum	Maximum	Std.Dev.	Median
Ca	**278661,54**	**13**	**238475,00**	**315500,00**	**31233,07**	**297575,00**	**294313,33**	**15**	**243050,00**	**326925,00**	**31642,84**	**308625,00**
Sr	**390,43**	**13**	**232,18**	**532,68**	**112,23**	**418,43**	**347,91**	**15**	**224,43**	**494,18**	**83,45**	**324,18**
Zn	**406,06**	**13**	**117,28**	**2247,00**	**567,93**	**229,65**	**160,97**	**15**	**96,58**	**282,00**	**52,83**	**136,98**
Pb	**2,22**	**13**	**0,14**	**19,86**	**5,31**	**0,76**	**0,24**	**15**	**-0,09**	**0,95**	**0,24**	**0,19**
Mn	146,40	13	45,50	260,75	68,28	142,75	110,45	15	13,75	295,75	94,98	63,00
Fe	340,25	13	135,75	795,00	207,09	229,25	363,00	15	46,50	1002,50	275,17	198,75
Mg	**933,77**	**13**	**638,50**	**1173,00**	**160,64**	**984,00**	**1029,65**	**15**	**686,50**	**1350,25**	**165,60**	**1077,25**
K	79,30	13	38,73	145,80	30,82	69,20	74,09	15	36,85	137,63	28,49	67,05
Na	2345,75	13	1527,50	3465,00	646,96	2285,75	2298,28	15	1464,75	3636,50	745,19	2043,00
Cu	**5,44**	**13**	**2,10**	**10,89**	**2,42**	**5,31**	**4,19**	**15**	**1,46**	**8,29**	**2,02**	**4,27**
V	18,32	13	6,18	29,00	7,08	17,49	24,16	15	3,21	92,25	20,44	20,88
Cr	1,31	13	0,60	2,21	0,43	1,35	1,27	15	0,52	2,77	0,63	1,00
Co	0,70	13	0,32	1,25	0,30	0,62	0,63	15	0,29	1,28	0,26	0,60
Ni	10,91	13	4,27	27,13	8,12	6,99	7,91	15	3,01	14,95	3,63	7,91
As	1,35	13	0,45	3,67	1,00	1,13	1,46	15	0,69	2,77	0,69	1,23
Y	0,44	13	0,08	1,31	0,35	0,38	0,38	15	0,02	0,81	0,24	0,29
Cd	0,25	13	0,05	0,49	0,14	0,20	0,19	15	0,01	0,59	0,14	0,15
Ba	**57,10**	**13**	**13,72**	**98,00**	**27,57**	**58,55**	**40,97**	**15**	**19,19**	**70,53**	**18,18**	**37,30**
La	0,28	13	-0,05	0,97	0,33	0,14	0,21	15	-0,09	0,55	0,19	0,11
Ce	0,33	13	0,08	0,88	0,25	0,26	0,26	15	0,04	0,62	0,14	0,24
Pr	0,08	13	0,02	0,26	0,07	0,06	0,06	15	0,00	0,14	0,04	0,05
Nd	0,35	13	0,07	1,12	0,32	0,25	0,26	15	0,01	0,52	0,16	0,22
Sm	0,07	13	0,01	0,27	0,07	0,06	0,05	15	0,00	0,13	0,04	0,04
Eu	0,03	13	0,01	0,07	0,02	0,03	0,02	15	0,01	0,05	0,01	0,02
Gd	0,07	13	0,01	0,19	0,05	0,05	0,05	15	0,00	0,12	0,03	0,04

	Males						Females					
	Means	N	Minimum	Maximum	Std. Dev.	Median	Means	N	Minimum	Maximum	Std.Dev.	Median
Tb	0,01	13	0,00	0,04	0,01	0,01	0,01	15	0,00	0,02	0,01	0,01
Dy	0,07	13	0,01	0,19	0,05	0,06	0,06	15	0,01	0,12	0,03	0,05
Ho	0,01	13	0,00	0,04	0,01	0,01	0,01	15	0,00	0,02	0,01	0,01
Er	0,04	13	0,01	0,10	0,03	0,03	0,03	15	0,00	0,06	0,02	0,02
Tm	0,00	13	0,00	0,01	0,00	0,01	0,00	15	0,00	0,01	0,00	0,00
Yb	0,03	13	0,00	0,08	0,02	0,03	0,02	15	0,00	0,05	0,01	0,02
Lu	0,00	13	0,00	0,01	0,00	0,01	0,00	15	0,00	0,01	0,00	0,00
U	0,44	13	0,03	1,92	0,49	0,32	0,28	15	0,01	0,74	0,23	0,24

Table 2a. Contens of stable elements in the skeletons from the Mikulčice-Kostelisko burial site in relation to sex and grave goods.

Element	Grave goods	Males						Females					
	clas. Stloukal	Means	N	Minimum	Maximum	Std.Dev.	Median	Means	N	Minimum	Maximum	Std.Dev.	Median
Ca	2	287694,4	9	240750,0	315500,00	26810,73	298725,00	304254,50	11	243050,00	326925,00	23611,27	309450,00
	1	258337,5	4	238475,0	309925,00	34491,20	242475,00	266975,00	4	243825,00	323575,00	38149,77	250250,00
	All Grps	278661,5	13	238475,0	315500,00	31233,07	297575,00	294313,30	15	243050,00	326925,00	31642,84	308625,00
Sr	2	417,84	9	232,18	532,68	107,21	469,43	364,33	11	279,68	494,18	72,47	359,18
	1	328,74	4	259,18	493,43	111,37	281,18	302,74	4	224,43	450,43	106,23	268,06
	All Grps	390,43	13	232,18	532,68	112,23	418,43	347,91	15	224,43	494,18	83,45	324,18
Zn	2	275,59	8	117,28	618,50	162,06	265,23	153,78	11	119,68	266,75	44,12	134,65
	1	206,76	4	163,93	229,65	29,20	216,73	180,75	4	96,58	282,00	76,34	172,21
	All Grps	252,64	12	117,28	618,50	134,52	223,58	160,97	15	96,58	282,00	52,83	136,98
Pb	2	0,79	8	0,35	1,31	0,29	0,75	0,27	11	0,05	0,95	0,27	0,22
	1	0,65	4	0,14	1,18	0,47	0,64	0,18	4	0,11	0,26	0,06	0,17
	All Grps	0,75	12	0,14	1,31	0,34	0,75	0,25	15	0,05	0,95	0,23	0,19
Mg	2	966,50	9	638,50	1173,00	149,23	991,50	1045,68	11	762,50	1184,25	108,52	1079,75
	1	860,13	4	656,50	1041,75	182,73	871,13	985,56	4	686,50	1350,25	291,88	952,75
	All Grps	933,77	13	638,50	1173,00	160,64	984,00	1029,65	15	686,50	1350,25	165,60	1077,25
K	2	85,07	9	38,73	145,80	35,95	80,63	82,23	11	48,00	137,63	27,87	76,93

Element	Grave goods	Males						Females					
	clas. Stloukal	Means	N	Minimum	Maximum	Std.Dev.	Median	Means	N	Minimum	Maximum	Std.Dev.	Median
	1	66,33	4	61,08	73,45	5,25	65,39	51,71	4	36,85	74,50	16,98	47,75
	All Grps	79,30	13	38,73	145,80	30,82	69,20	74,09	15	36,85	137,63	28,49	67,05
Cu	2	5,54	9	2,10	10,89	2,66	4,37	4,54	11	2,16	8,29	2,01	4,27
	1	5,23	4	2,33	7,38	2,12	5,61	3,25	4	1,46	5,30	2,01	3,12
	All Grps	5,44	13	2,10	10,89	2,42	5,31	4,19	15	1,46	8,29	2,02	4,27
Ba	2	67,17	9	13,72	98,00	26,57	75,55	43,41	11	19,19	70,53	17,59	38,63
	1	34,47	4	22,39	52,25	13,04	31,61	34,24	4	19,23	64,68	20,69	26,52
	All Grps	57,10	13	13,72	98,00	27,57	58,55	40,97	15	19,19	70,53	18,18	37,30

Table 2b. Analysis of the variance of element content in the skeleton from Mikulčice-Kostelisko in relation to sex.

Group rich (Stloukal 1970) (Males=4, Females=4)									Group poor (Stloukal 1970) (Males = 9(8), Females =11)								
Element	F	SV effect	SV error	p	Levene p	Mann-Whitney p	Signif. AOV	Signif. MWh	Element	F	SV effect	SV error	p	Levene p	Mann-Whitney p	Signif. AOV	Signif. MWh
Ca	0,113	1	6	0,748	0,855	0,386			Ca	2,157	1	18	0,159	0,533	0,044		5%
Sr	0,114	1	6	0,747	0,908	0,564			Sr	1,766	1	18	0,201	0,176	0,210		
Zn	0,405	1	6	0,548	0,300	0,564			Zn	5,746	1	17	0,028	0,029	0,048	5%	5%
Pb	4,073	1	6	0,090	0,007	0,149	10%		Pb	16,309	1	17	0,001	0,776	0,002	0,1%	1,0%
Mn	0,191	1	6	0,677	0,525	0,386			Mn	1,066	1	18	0,316	0,141	0,184		
Fe	0,010	1	6	0,922	0,782	0,564			Fe	0,156	1	18	0,697	0,302	0,621		
Mg	0,531	1	6	0,494	0,304	0,386			Mg	1,888	1	18	0,186	0,452	0,087		10%
K	2,704	1	6	0,151	0,084	0,248			K	0,040	1	18	0,844	0,371	0,790		
Na	0,005	1	6	0,947	0,800	0,773			Na	0,032	1	18	0,860	0,889	0,676		
Cu	1,846	1	6	0,223	0,696	0,083		10%	Cu	0,923	1	18	0,349	0,356	0,470		
V	0,004	1	6	0,950	0,903	1,000			V	1,006	1	18	0,329	0,175	0,543		
Cr	0,008	1	6	0,933	0,227	1,000			Cr	0,033	1	18	0,859	0,247	0,518		
Co	0,147	1	6	0,715	0,242	0,773			Co	0,534	1	18	0,474	0,883	0,305		
Ni	0,395	1	6	0,553	0,233	0,564			Ni	1,205	1	18	0,287	0,036	0,790		
As	0,115	1	6	0,746	0,048	0,564			As	0,163	1	18	0,691	0,347	0,342		

Group rich (Stloukal 1970) (Males=4, Females=4)									Group poor (Stloukal 1970) (Males = 9(8), Females =11)								
Element	F	SV effect	SV error	p	Levene p	Mann-Whitney p	Signif. AOV	Signif. MWh	Element	F	SV effect	SV error	p	Levene p	Mann-Whitney p	Signif. AOV	Signif. MWh
Y	0,231	1	6	0,648	0,698	0,564			Y	0,858	1	18	0,367	0,287	0,224		
Cd	0,000	1	6	0,983	0,318	0,564			Cd	1,844	1	18	0,191	0,284	0,110		
Ba	0,000	1	6	0,986	0,411	0,773			Ba	5,750	1	18	0,028	0,273	0,037	5%	5%
La	0,841	1	6	0,394	0,161	0,564			La	0,144	1	18	0,709	0,057	0,970		
Ce	0,000	1	6	0,989	0,725	0,773			Ce	1,025	1	18	0,325	0,150	0,425		
Pr	0,015	1	6	0,907	0,757	0,773			Pr	1,142	1	18	0,299	0,050	0,361		
Nd	0,043	1	6	0,842	0,612	0,564			Nd	1,498	1	18	0,237	0,042	0,239		
Sm	0,003	1	6	0,956	0,760	0,772			Sm	1,515	1	18	0,234	0,148	0,210		
Eu	0,262	1	6	0,627	1,000	0,663			Eu	1,483	1	18	0,239	0,081	0,285		
Gd	0,037	1	6	0,855	0,719	0,773			Gd	0,911	1	18	0,352	0,088	0,287		
Tb	0,235	1	6	0,645	0,379	0,653			Tb	0,903	1	18	0,355	0,193	0,354		
Dy	0,711	1	6	0,431	0,537	0,384			Dy	0,974	1	18	0,337	0,087	0,425		
Ho	0,086	1	6	0,780	0,604	0,770			Ho	0,767	1	18	0,393	0,241	0,356		
Er	0,149	1	6	0,713	0,859	0,772			Er	1,472	1	18	0,241	0,356	0,209		
Tm	0,000	1	6	1,000	0,134	1,000			Tm	1,084	1	18	0,312	0,667	0,368		
Yb	0,267	1	6	0,624	0,530	0,559			Yb	0,981	1	18	0,335	0,396	0,269		
Lu	0,000	1	6	1,000	0,134	1,000			Lu	0,778	1	18	0,389	0,346	0,422		
U	0,112	1	6	0,749	0,754	0,564			U	1,212	1	18	0,286	0,220	0,470		

Table 2c. Analysis of the variance of element content in the skeleton from Mikulčice-Kostelisko in relation to sex.

Group poor (Stloukal 1970) (Males = 9(8), Females=11)								
Ratio	F	SV effect	SV error	p	Levene p	Mann-Whitney p	Signif. AOV	Signif. MWh
Sr/Ca	4,492	1	18	0,048	0,139	0,053	5%	5%
Zn/Ca	6,269	1	17	0,023	0,027	0,010	5%	1%
Pb/Ca	20,979	1	17	0,0003	0,627	0,002	0,1%	1%
Mn/Ca	0,989	1	18	0,333	0,212	0,119		
Fe/Ca	0,015	1	18	0,902	0,582	0,621		

Group poor (Stloukal 1970) (Males = 9(8), Females=11)

Ratio	F	SV effect	SV error	p	Levene p	Mann-Whitney p	Signif. AOV	Signif. MWh
Mg/Ca	0,172	1	18	0,683	0,828	0,425		
K/Ca	0,281	1	18	0,602	0,184	0,676		
Na/Ca	0,225	1	18	0,641	0,758	0,382		
Cu/Ca	1,577	1	18	0,225	0,380	0,305		
V/Ca	0,684	1	18	0,419	0,196	0,732		
Cr/Ca	0,188	1	18	0,670	0,383	0,382		
Co/Ca	0,647	1	18	0,432	0,882	0,210		
Ni/Ca	1,758	1	18	0,201	0,012	0,732		
As/Ca	0,109	1	18	0,745	0,418	0,425		
Y/Ca	1,188	1	18	0,290	0,177	0,184		
Cd/Ca	1,997	1	18	0,175	0,274	0,119		
Ba/Ca	7,651	1	18	0,013	0,420	0,017	5%	5%
La/Ca	0,240	1	18	0,630	0,055	0,970		
Ce/Ca	1,382	1	18	0,255	0,085	0,382		
Pr/Ca	1,435	1	18	0,247	0,043	0,342		
Nd/Ca	1,775	1	18	0,199	0,039	0,239		
Sm/Ca	1,671	1	18	0,212	0,119	0,210		
Eu/Ca	1,965	1	18	0,178	0,049	0,210		
Gd/Ca	1,240	1	18	0,280	0,064	0,239		
Tb/Ca	1,303	1	18	0,269	0,117	0,160		
Dy/Ca	1,323	1	18	0,265	0,063	0,425		
Ho/Ca	1,061	1	18	0,317	0,166	0,271		
Er/Ca	1,892	1	18	0,186	0,201	0,160		
Tm/Ca	1,361	1	18	0,259	0,363	0,287		
Yb/Ca	1,298	1	18	0,269	0,228	0,210		
Lu/Ca	1,078	1	18	0,313	0,218	0,323		
U/Ca	1,132	1	18	0,301	0,260	0,470		

Table 3. Association with age of the trace element content within the burial site Mikulčice- Kostelisko using Spearman's rank correlation coefficient.

	Male				Female				
	Spearman R	t (N-2)	Level p	Stat. Significant		Spearman R	t (N-2)	Level p	Stat.Ssignificant
age & Ca	-0,209	-0,71	0,492		age & Ca	-0,289	-1,09	0,296	
age & Sr	-0,439	-1,62	0,134		age & Sr	-0,192	-0,71	0,493	
age & Zn	-0,424	-1,48	0,170		age & Zn	0,295	1,11	0,286	
age & Pb	-0,058	-0,19	0,857		age & Pb	-0,101	-0,37	0,721	
age & Mn	-0,313	-1,09	0,298		age & Mn	0,189	0,69	0,501	
age & Fe	-0,290	-1,00	0,337		age & Fe	-0,259	-0,97	0,351	
age & Mg	-0,325	-1,14	0,279		age & Mg	0,330	1,26	0,229	
age & K	-0,307	-1,07	0,308		age & K	0,278	1,04	0,316	
age & Na	0,513	1,98	0,073		age & Na	0,343	1,32	0,210	
age & Cu	-0,250	-0,85	0,411		age & Cu	-0,297	-1,12	0,283	
age & V	-0,404	-1,47	0,171		age & V	-0,293	-1,10	0,289	
age & Cr	-0,303	-1,05	0,314		age & Cr	0,170	0,62	0,545	
age & Co	-0,320	-1,12	0,286		age & Co	-0,325	-1,24	0,238	
age & Ni	-0,548	-2,17	0,053	5%	age & Ni	-0,444	-1,79	0,097	
age & As	-0,215	-0,73	0,480		age & As	0,356	1,38	0,192	
age & Y	-0,579	-2,36	0,038	5%	age & Y	-0,078	-0,28	0,781	
age & Cd	-0,508	-1,95	0,077		age & Cd	0,284	1,07	0,305	
age & Ba	-0,482	-1,82	0,095		age & Ba	-0,127	-0,46	0,652	
age & La	-0,396	-1,43	0,181		age & La	-0,169	-0,62	0,547	
age & Ce	-0,456	-1,70	0,117		age & Ce	-0,067	-0,24	0,812	
age & Pr	-0,503	-1,93	0,080		age & Pr	-0,071	-0,26	0,802	
age & Nd	-0,528	-2,06	0,064		age & Nd	-0,090	-0,32	0,751	
age & Sm	-0,434	-1,60	0,139		age & Sm	-0,014	-0,05	0,960	
age & Eu	-0,514	-1,99	0,072		age & Eu	-0,308	-1,17	0,264	
age & Gd	-0,470	-1,77	0,105		age & Gd	-0,159	-0,58	0,571	
age & Tb	-0,491	-1,87	0,088		age & Tb	-0,109	-0,39	0,700	
age & Dy	-0,572	-2,31	0,041	5%	age & Dy	-0,019	-0,07	0,947	

Male					Female				
	Spearman R	t (N-2)	Level p	Stat. Significant		Spearman R	t (N-2)	Level p	Stat.Ssignificant
age & Ho	-0,483	-1,83	0,095		age & Ho	0,002	0,01	0,995	
age & Er	-0,592	-2,44	0,033	5%	age & Er	-0,015	-0,05	0,957	
age & Tm	-0,566	-2,28	0,044	5%	age & Tm	0,140	0,51	0,618	
age & Yb	-0,701	-3,26	0,008	1%	age & Yb	0,122	0,44	0,665	
age & Lu	-0,546	-2,16	0,053	5%	age & Lu	-0,215	-0,79	0,442	
age & U	-0,402	-1,45	0,174		age & U	0,185	0,68	0,510	

Tables 4a, 4b. Analysis of the variance of the double sorting of the influence of sex and grave equipment on the content of trace elements in the skeletons from the Mikulčice-Kostelisko burial site.

	Model with Interactions			Model without Interaction		
Element	Sex p	Grave goods p	Inter–action	Sex p	Grave Goods p	Element
Ca		0,01**	significant interaction		0,01**	Ca
Sr		0,07			0,06	Sr
Zn	0,0900			0,02*		Zn
Pb	0,0005***			0,0001***		Pb
Mn						Mn
Fe						Fe
Mg						Mg
K		0,05*			0,04*	K
Na		0,01**			0,01**	Na
Cu						Cu
V						V
Cr						Cr
Co		0,08			0,08	Co
Ni						Ni
As						As

	Model with interactions			Model without Interaction		
Element	Sex p	Grave Goods p	Inter-action	Sex p	Grave goods p	elementE
Sr/Ca	0,0900		unsignificant interaction	0,03*		Sr/Ca
Zn/Ca	0,0700			0,0700		Zn/Ca
Pb/Ca	0,0003***			0,0003***		Pb/Ca
Mn/Ca						Mn/Ca
Fe/Ca						Fe/Ca
Mg/Ca						Mg/Ca
K/Ca						K/Ca
Na/Ca		0,005**			0,004**	Na/Ca
Cu/Ca				0,0600		Cu/Ca
V/Ca						V/Ca
Cr/Ca						Cr/Ca
Co/Ca						Co/Ca
Ni/Ca						Ni/Ca
As/Ca						As/Ca
Y/Ca						Y/Ca

	Model with Interactions			Model without Interaction		
Element	Sex p	Grave goods p	Inter–action	Sex p	Grave Goods p	Element
Y		0,08	significant interaction		0,08	Y
Cd						Cd
Ba		0,02*		0,05*	0,03*	Ba
La						La
Ce		0,07			0,06	Ce
Pr		0,08			0,07	Pr
Nd		0,09			0,09	Nd
Sm		0,10			0,10	Sm
Eu		0,03*			0,04*	Eu
Gd		0,07			0,07	Gd
Tb		0,06			0,06	Tb
Dy		0,07			0,07	Dy
Ho						Ho
Er		0,06			0,06	Er
Tm		0,04*			0,04*	Tm
Yb		0,05*			0,05*	Yb
Lu						Lu
U						U

	Model with interactions			Model without Interaction		
Element	Sex p	Grave Goods p	Inter-action	Sex p	Grave goods p	elementE
Cd/Ca			unsignificant interaction			Cd/Ca
Ba/Ca	0,0900	0,04*		0,02*	0,04*	Ba/Ca
La/Ca						La/Ca
Ce/Ca						Ce/Ca
Pr/Ca						Pr/Ca
Nd/Ca						Nd/Ca
Sm/Ca						Sm/Ca
Eu/Ca		0,08			0,09	Eu/Ca
Gd/Ca						Gd/Ca
Tb/Ca		0,09			0,10	Tb/Ca
Dy/Ca						Dy/Ca
Ho/Ca						Ho/Ca
Er/Ca		0,10				Er/Ca
Tm/Ca		0,10			0,10	Tm/Ca
Yb/Ca		0,09			0,10	Yb/Ca
Lu/Ca					0,09	Lu/Ca
U/Ca						U/Ca

Stable C, N Isotopes in Human Skeletal Material from the Great Moravian Burial Site at Mikulčice-Kostelisko

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The Great Moravian burial site at Mikulčice-Kostelisko is the largest such site in the subcastle of the Mikulčice power centre, which was one of the main centres of the Great Moravian empire. Analysis of stable C, N isotopes from bone collagen was conducted in 10 skeletons. The skeletons of the Mikulčice burial site (N=10) contain the following range of stable nitrogen isotopes in their bone collagen ($\delta\ ^{15}N$ + 8.8 to 12.5 ‰, with an average of 10.72 ± 1.17 ‰) and of stable carbon isotopes ($\delta\ ^{13}C$ -17.8 to -19.6 ‰, with an average of -18.89 ± 0.5 ‰). During analysis of the stable C, N isotopes from ten skeletons of the Mikulčice burial site, significant social differences were discovered. The averages of stable carbon isotopes in skeletons from rich graves (N-8) (-18.76± 0.46 ‰) are greater than those from poor graves (N- 2) (-19. 42±0.30 ‰) (p= 0.0307) according to Stloukal´s categorisation of grave goods. On comparing the mean values of the group 2 rich graves (N-5) according to Hrubý and those of the united groups 3,4,5 of poor graves (N-5), the stable nitrogen isotopes ($\delta^{15}N$ 11.38 ± 0.82 ‰) in rich graves are higher than in the groups of poor graves ($\delta^{15}N$ 10.07 ± 1.15 ‰) (p= 0.117). Wealth meant a greater intake of the much-favoured millet (C4 of the photosynthetic cycle) and more meat in the diet.

Key words: Great Moravian population – stable C, N isotopes – skeletal remains – social status – diet

1. Introduction

The stable C,N isotopes were analysed in skeletons from the Slavic burial site at Mikulčice-Kostelisko (Poláček/Marek 1995) with the aim of reconstructing the diet of the given population and of attempting to distinguish social differences on the basis of the organic bone component-collagen. Collagen contains both amino acids produced in the body as well as essential acids acquired from food, predominantly meat. It is thus the most suitable material for reflecting the diet of the objects studied.

2. Method and materials

Human skeletons: Samples of ribs were taken from the skeletons of males (N-5) and females (N-5) from the Mikulčice burial site deposited at the National Museum. These were used to analyse the stable ^{13}C, ^{12}C and ^{15}N, ^{14}N isotopes from the organic component of collagen (Katzenberg 2008; Smrčka 2005).

Samples were taken from grave 1605 (woman 20-25 years), grave 1648 (woman 20-30 years), grave 1742 (woman 20-25 years), grave 1777A (woman 30-40 years), grave 1973 (woman 40-60 years), grave 1809 (man 40-50 years), grave 1861

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Table 1. Summary of the ratios of carbon and nitrogen isotopes in the analysed skeletons from the Slavic burial site at Mikulčice-Kostelisko (with determination of sex and grave equipments according to Stloukal and Hrubý).

sample	N%	C%	C/N	δ15N (‰)	δ13C (‰)	sex	classif. Stloukal (1970)	classif. Hrubý (1955)
Mikulčice-Kostelisko, grave No. 1605 (Inv.No.16799)	5.3	19.5	3.7	11.4	-19.6	female	2	5
Mikulčice-Kostelisko, grave No. 1648, (Inv.No.16831)	11.4	34.9	3.1	10.8	-18.8	female	1	4
Mikulčice-Kostelisko, grave No. 1742, (Inv.No.16889)	9.9	28.6	2.9	11.7	-18.9	female	1	2
Mikulčice-Kostelisko, grave No.1777A (Inv.No.16902)	9.9	28.4	2.9	8.8	-19.2	female	1	3
Mikulčice-Kostelisko, grave No. 1973 (Inv.No.17034)	4.2	12.7	3.0	10.4	-17.8	female	1	4
Mikulčice-Kostelisko, grave No. 1809 (Inv.No.16923)	4.9	14.5	3.0	10.8	-18.4	male	1	2
Mikulčice-Kostelisko, grave No. 1861 (Inv.No.16951)	6.1	18.2	3.0	9.0	-19.2	male	2	4
Mikulčice-Kostelisko, grave No. 1908 (Inv.No. 16998)	13.3	37.8	2.8	11.6	-18.8	male	1	2
Mikulčice-Kostelisko, grave No. 1975 (Inv.No.17031)	4.2	13.1	3.1	12.5	-19.1	male	1	2
Mikulčice-Kostelisko, grave No. 1912 (Inv.No.17167)	7.4	22.0	3.0	10.3	-19.2	male	1	2

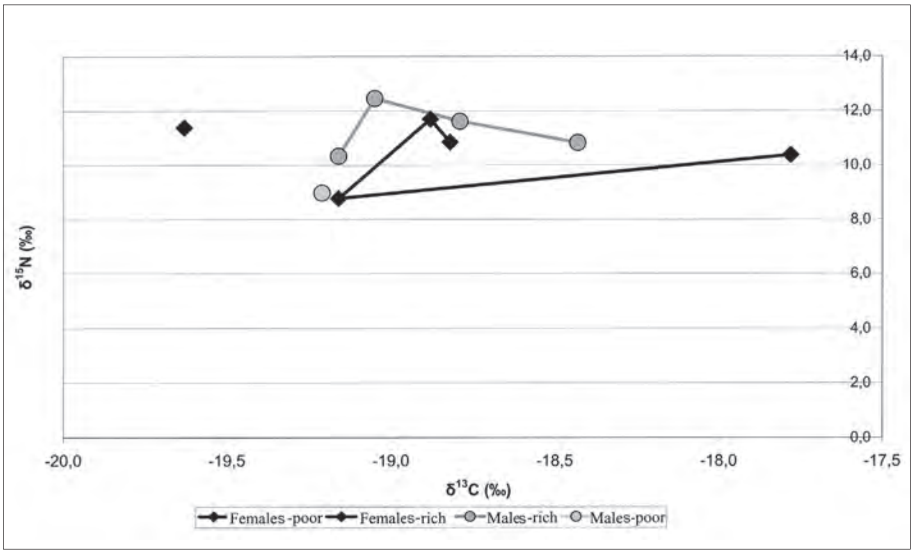
(man 20-30 years), grave 1908 (man 40-50 years), grave 1975 (man 50-60 years) and grave 1912 (man 40-50 years) (Velemínský et al. 2005).

Categorisation of grave goods according to Stloukal (1970) (1= rich graves, 2 = poor graves) and according to V. Hrubý (1955) (1, 2 = rich graves; 3, 4, 5 = poor graves) was used to distinguish the social differences at the burial site.

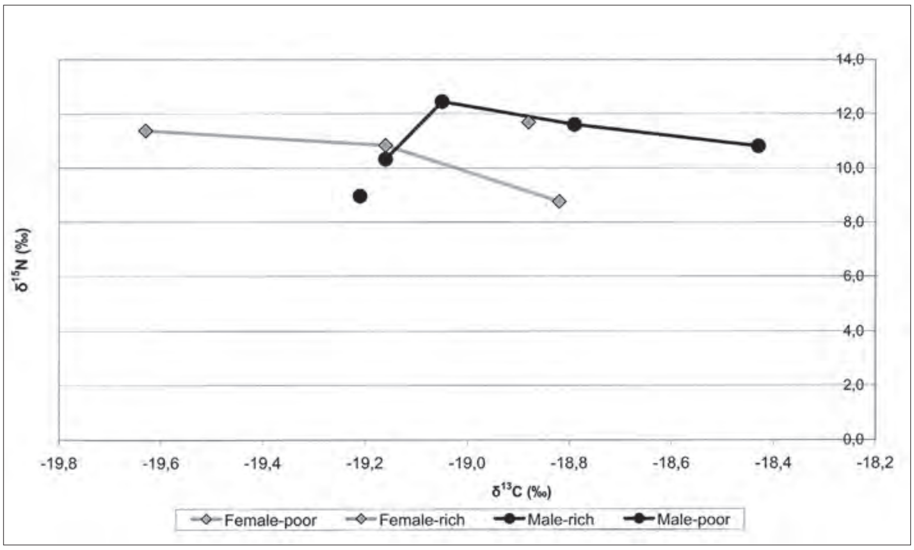
2.1 Processing of samples

For reliable isotope analysis, it is essential to preserve the isotopic composition of the initial organic carbon and nitrogen, and to remove foreign and inorganic material. The well-established method, also used for radiocarbon dating (Stafford/Brendel/Duhamel 1988), was used. Bone samples were broken down to a size of below 1 cm and first cleaned using ultrasound in distilled water. The fragments were then dried at a temperature of 50°C, homogenised to a size of < 63μm and extracted using methanol and water. The remaining material was mineralised (to remove carbonate compounds) using 4°C 0.5N HCl at a constant pH, rinsed with distilled water and again dried at 50°C. Alkalic soaking of samples was avoided in order to minimise collagen losses.

The elemental composition of samples, i.e. the content of carbon and nitrogen and the analysis of $\delta^{13}C$ and $\delta^{15}N$, was determined. Analysis was conducted using standard procedures for this type of material – upon burning the collagen in an elemental analyser (Fisons 1108), the resulting products are chromatographically divided into nitrogen and carbon dioxide and analysed in the Mat 251 isotope mass spectrometer by comparing these with reference gases of known isotopic composition. The whole process is controlled with the aid of international reference materials NBS 22 (NIST USA, $\delta^{13}C$ - 29,75‰) and NZ 1, NZ 2 (IAEA Vienna $\delta^{15}N$ 0 and 20‰).



Graph 1. Ratios of carbon and nitrogen isotopes in the skeletons from the Slavic burial site at Mikulčice-Kostelisko, differentiated by sex and grave goods according to Stloukal 1970.



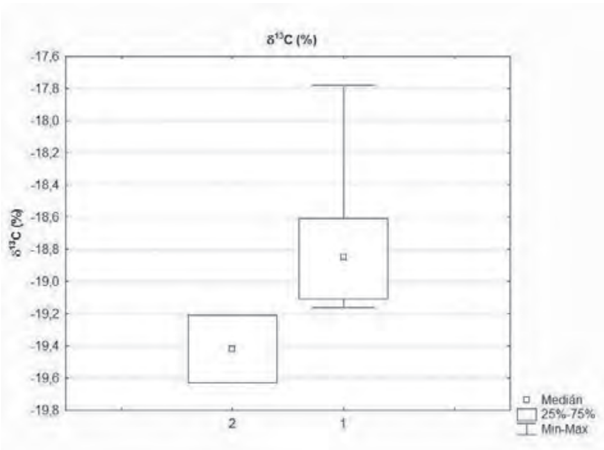
Graph 2. Rations of carbon and nitrogen isotopes in the skeletons from the Slavic burial site at Mikulčice-Kostelisko differentiated by sex and grave goods according to Hrubý 1955.

The sample size was optimised so that the error of measurement did not exceed 0.15‰. The measured data are listed in Table 1.

3. Results

3.1 Reconstruction of diet with the aid of carbon and nitrogen isotopes.

The skeletons from the Mikulčice burial site (N = 10) have the following range of stable nitrogen isotopes in their bone collagen ($\delta^{15}N$ + 8.8 to 12.5‰, with an average of 10.72 ± 1.17‰) and of stable carbon isotopes ($\delta^{13}C$ - 17.8 to - 19,6‰, with an average of - 18.89 ± 0.5‰). This is a population mainly dependent on inland plants of the C3 photosynthesis type (wheat),



Graph 3. Ratios of carbon isotopes in the skeletons of rich (1) and poor (2) graves from the Slavic burial site at Mikulčice-Kostelisko according to Stloukal's garniture of grave goods.

Table 2. Descriptive statistics with arithmetic averages, standard deviations of the ratios of carbon and nitrogen isotopes in five female (F= female) and five male (M = male) and the whole analysed group from the Slavic burial site at Mikulčice-Kostelisko.

Sex	Age-means	N% N	N% Means	N% Std. Dev.	C% Means	C% Std. Dev.	C/N Means	C/N Std. Dev.	δ¹⁵N (%) Means	δ¹⁵N (%) Std Dev.	δ¹³C (%) Means	δ¹³C (%) Std Dev.
F	35.0	5	8.13	3.16	24.79	8.69	3.11	0.34	10.61	1.15	-18.85	0.68
M	41.0	5	7.19	3.63	21.13	9.94	2.96	0.11	10.84	1.32	-18.93	0.32
all groups	38.0	10	7.66	3.25	22.96	9.01	3.04	0.25	10.72	1.17	-18.89	0.50

Table 2a. Comparison of the mean ratios of carbon and nitrogen isotopes according to sex in five female (F= female) and five male (M = male) using the T-test and non-parametric Mann- Whitney test.

	Mean F	Mean M	Std. Dev. F	Std.Dev. M	Std. Dev. F	Number M	t	sv	p	F-rate variance	p variance	Z	M-Wh p	Stat. signif.
N%	8.13	7.19	3.16	3.63	5	5	0.43	8	0.675	1.32	0.797	0.31	0.754	
C%	24.79	21.13	8.69	9.94	5	5	0.62	8	0.552	1.31	0.800	0.52	0.602	
C/N	3.11	2.96	0.34	0.11	5	5	0.93	8	0.378	10.29	0.044	0.63	0.531	
$\delta^{15}N$ (%)	10.61	10.84	1.15	1.32	5	5	-0.29	8	0.780	1.32	0.794	-0.10	0.917	
$\delta^{13}C$ (%)	-18.85	-18.93	0.68	0.32	5	5	0.22	8	0.832	4.46	0.177	0.00	1.000	

Table 3. Descriptive statistics with arithmetic averages, standard deviations of the ratios of carbon and nitrogen isotopes in the bones of eight rich (1) and two poor (2) graves from the burial site at Mikulčíce-Kostelisko according to Stloukal´s garniture of grave goods.

Group "Stloukal 1970"	Age-means	N% N	N% Means	N% Std. Dev.	C% Means	C% Std. Dev.	C/N Means	C/N Std. Dev.	δ¹⁵N (%) Means	δ¹⁵N (%) Std. Dev.	δ¹³C (%) Means	δ¹³C (%) Std Dev.
1	40.6	8	8.15	3.49	23.99	9.91	2.96	0.11	10.86	1.11	-18.76	0.46
2	27.5	2	5.73	0.57	18.83	0.89	3.34	0.52	10.18	1.70	-19.42	0.30
all groups	38.0	10	7.66	3.25	22.96	9.01	3.04	0.25	10.72	1.17	-18.89	0.50

Table 3a. Comparison of mean values of the ratios of carbon and nitrogen isotopes using the T- test and Mann- Whitney test in the skeletons divided according to Stloukal´s garniture of grave goods into rich (1) and poor (2). Between groups 1 and 2, there is a significant relationship for $\delta^{13}C$ (at a 5% level of significance).

	Mean 2	Mean 1	Std. Dev. 2	Std. Dev. 1	Number 2	Number 1	t	sv	p	F-rate variance	p variance	Z	M-Wh p	stat. signif.
N%	5.73	8.15	0.57	3.49	2	8	-0.94	8	0.376	37.11	0.252	-0.52	0.602	
C%	18.83	23.99	0.89	9.91	2	8	-0.70	8	0.501	123.67	0.138	-0.52	0.602	

	Mean 2	Mean 1	Std. Dev. 2	Std. Dev. 1	Number 2	Number 1	t	sv	p	F-rate variance	p variance	Z	M-Wh p	stat. signif.
C/N	3.34	2.96	0.52	0.11	2	8	2.27	8	0.053	22.80	0.004	1.04	0.296	
δ15N (%)	10.18	10.86	1.70	1.11	2	8	-0.72	8	0.492	2.34	0.339	-0.52	0.602	
δ13C (%)	-19.42	-18.76	0.30	0.46	2	8	-1.88	8	0.097	2.42	0.919	-2.09	0.037	5%

Table 4. Descriptive statistical characteristics of the ratios of C,N isotopes in groups of skeletons at the burial site, divided into groups 1-5 (2.-rich, 3,4,5 poor graves) according to Hrubý´s garniture of grave goods.

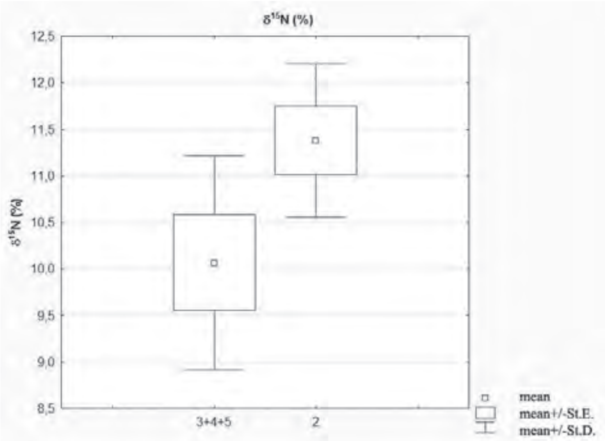
Group "Hrubý 1955"	Age-means	N% N	N% Means	N% Std Dev.	C% Means	C% Std. Dev.	C/N Means	C/N Std. Dev.	$\delta^{15}N$ (%) Means	$\delta^{15}N$ (%) Std. Dev.	$\delta^{13}C$ (%) Means	$\delta^{13}C$ (%) Std. Dev.
2	41.0	5	7.94	3.74	23.20	10.25	2.94	0.11	11.38	0.82	-18.86	0.28
3	42.5	1	9.88	0.00	28.35	0.00	2.86	0.00	8.77	0.00	-19.16	0.00
4	35.0	3	7.24	3.73	21.93	11.52	3.02	0.07	10.06	0.97	-18.60	0.74
5	27.5	1	5.32	0.00	19.46	0.00	3.70	0.00	11.38	0.00	-19.63	0.00
all groups	38.0	10	7.66	3.25	22.96	9.01	3.04	0.25	10.72	1.17	-18.89	0.50

Table 5. Descriptive statistical characteristics of the ratios of C,N isotopes in the groups of rich (2) and merged poor (3,4,5) skeletons differentiated according to Hrubý´s grave goods at the Mikulčice-Kostelisko burial site.

Mod. classif. "Hrubý 1955"	Age-means	N% N	N% Means	N% Std. Dev.	C% Means	C% Std. Dev.	C/N Means	C/N Std. Dev.	$\delta^{15}N$ (%) Means	$\delta^{15}N$ (%) Std. Dev.	$\delta^{13}C$ (%) Means	$\delta^{13}C$ (%) Std. Dev.
3+4+5	35.0	5	7.39	3.10	22.72	8.80	3.13	0.33	10.07	1.15	-18.92	0.70
2	41.0	5	7.94	3.74	23.20	10.25	2.94	0.11	11.38	0.82	-18.86	0.28
all groups	38.0	10	7.66	3.25	22.96	9.01	3.04	0.25	10.72	1.17	-18.89	0.50

Table 5a. Comparison of mean values of the ratios of carbon and nitrogen isotopes using the T-test and Mann- Whitney test in skeletons differentiated according to Hrubý´s garniture of grave goods as poor (3,4,5) and rich (2). Between groups 3,4,5 and group 2, there is a significant relationship for $\delta^{15}N$ (at a 10% level of significance).

	Mean 3+4+5	Mean 2	Std. Dev. 3+4+5	Std. Dev. 2	Number 3+4+5	Number 2	t	sv	p	F-rate variance	p variance	Z	M-Wh p	Stat. signif.
N%	7.39	7.94	3.10	3.74	5	5	-0.25	8	0.806	1.46	0.724	-0.10	0.917	
C%	22.72	23.20	8.80	10.25	5	5	-0.08	8	0.939	1.36	0.774	-0.31	0.754	
C/N	3.13	2.94	0.33	0.11	5	5	1.16	8	0.279	8.94	0.057	1.04	0.296	10%
$\delta^{15}N$ (%)	10.07	11.38	1.15	0.82	5	5	-2.08	8	0.072	1.96	0.532	-1.57	0.117	
$\delta^{13}C$ (%)	-18.92	-18.86	0.70	0.28	5	5	-0.17	8	0.868	6.18	0.106	-0.84	0.403	



Graph 4. Ratios of nitrogen isotopes of rich (2) and poor (3,4,5) graves from the Slavic burial site at Mikulčice-Kostelisko according to Hrubý´s garniture of grave goods .

and in some individuals on the C4 cycle type (Table 1). For example, the woman from grave 1973 (40-60 years) with very rich grave goods (δ^{13}C - 17.8‰) and probably the man from grave 1809 (δ^{13}C - 18.4‰) had a diet of the C4 photosynthetic cycle type (corresponding to millet). The others correspond to the C3 type of cycle (wheat) (Graph 1, 2).

The averages of stable nitrogen isotopes in male s(N = 5) (10.84 ± 1.32‰) are insignificantly higher than in females (N = 5) (10.61 ± 1.15‰).

The averages of stable carbon isotopes in females (N = 5) (- 18.85 ± 0.68‰) are insignificantly higher than in males (N = 5) (- 18.93 ± 0.32‰) (Table 2, 2a).

3.2 Social differences at the burial site

Because of the small number of observations, only the basic characteristics of categorisation according to sex and grave goods as per Stloukal were calculated. The differences in medians between the Stloukal first group (rich graves) and Stloukal second group (poor graves) were tested using the Mann – Whitney test only for both sexes together (Table 3).

The difference was manifested in the δ^{13} C variable ($z = -2.1$, $p = 0.037$). The averages of stable carbon isotopes in skeletons from rich graves (N = 8) (- 18.76 ± 0.46‰) are greater than in the case of poor graves (N = 2) (- 19.42 ± 0.30‰) (p = 0,0307) according to Stloukal's categorisation of grave goods (Table 3a, Graph 3).

Two of the four rich males, according to the categorisation of grave goods as per Hrubý, have δ^{15}N greater than poor females (see Graph 2). When comparing the mean values of rich graves (N-5) from group "2" according to Hrubý (Table 4) and the united groups 3, 4, 5 (Table 5) of poor graves (N = 5), the stable nitrogen isotopes (δ^{15}N 11.38 ± 0.82‰) in the rich graves are higher than in the group of poor graves (δ^{15}N 10.07 ± 1.15‰) ($p = 0.117$) (Table 5a; Graph 4).

4. Discussion

In the case of the C, N isotopes, we did not discover any difference between the sexess, but we did uncover social differences between the rich and the poor, namely involving the type of cereal diet used and the access to a meat-based diet.

The rich appear to give preference to a cereal diet of the C4 photosynthetic cycle, represented by millet.

An example of this is the females from grave No. 1973 (40-60 years) with the rich grave goods (δ^{13}C - 17.8‰) and the males from grave No.1809 (δ^{13}C - 18.4‰).

According to historical reports, The Slavs appear to have taken a liking to millet. It was an expensive cereal, though. Millet purée was often a festive or prestigious food (Beranová 2005).

At the same time, the rich probably had more meat in their diet than did the poor. An example of this is the man from grave No.1975 (δ^{15}N 12.5‰) with the most meat-based diet (Table 1, Graph 2).

5. Conclusion

During the analysis of stable C,N isotopes of 10 skeletons from the Mikulčice burial site, significant social differences were discovered. It must be taken into account, though, that the tested sample was very small. It may thus be presumed that the diet of richer, socially more successful individuals included a greater quantities of meat and the favoured millet.

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Anthropological and epidemiological characterization of Great-Moravian population in connection with the social and economic structure

Skeletal Asymmetry of Locomotor Apparatus at Great Moravian Population

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Monitoring the asymmetry rate of different parts of human body can contribute to population studies. It may be connected with the social structure of society and the quality of living conditions. Asymmetry can be the result of non-specific stress affecting the organism or preference for the right or the left side of body during specific activities. In this paper, directional (DA), fluctuating (FA) asymmetry, the antisymmetry (AS) and possibly cross-asymmetry of the dimensions of the upper and lower limb bones was assessed and these indicators were used to compare the differences within and among the medieval, and the recent population. A sample of medieval population came from two Great-Moravian cemeteries Mikulčice-Kostelisko (78 males, 132 females) and Prušánky (66 male, 69 female). A collection from Bohemia from the first half of the 20th century (143 males, and 157 females) was used as a comparative sample of recent population. Only adult individuals were selected. Males and females were evaluated separately. DA was recorded in most dimensions of the studied bones. In the upper limb it was mostly expressed on the humerus, and except for the clavicle it was always in favour of the right side. On the lower limb bones, DA was less frequent than in the upper limb bones and in most cases it was in favour of the left side. In addition, on the lower limb bones, it was more expressed on the transversal, sagittal and circumferential dimensions of the diaphyses and epiphyses than on the length dimensions. The FA values were very low and almost negligible in relation to the size, nevertheless FA was markedly more frequent on the lower than on the upper limb. In contrast to the Great Moravian population, the recent population had higher FA values and also DA was found more often there. All the long bones of the right upper limb as well as the left femur of most individuals in both populations are statistically significantly longer. However, in most individuals cross-asymmetry was not confirmed. AS was not observed.

Key words: Directional asymmetry – fluctuating asymmetry – antisymmetry – cross-asymmetry – bones of the upper and lower limb – Great Moravian population – recent population

1. Introduction

Asymmetry is a feature commonly found in nature, it is one of the fundamental characteristics of living organisms. Of course, the human body is also asymmetric – apart from striking variations, very slight deviations (in the range of 1%, or less from a trait size) are encountered which cannot be noticeable at first sight. These deviations may provide many clues about the person's living conditions, or about health (Palmer 1996). But if the deviations are too marked, they may be evidence of pathologic asymmetry (Burian 1939). Knowledge of asymmetry may be used for the cognition of the ontogenetic principals and their disturbances. Asymmetry indicates fitness assessment of organisms, their evolutional stability, health, etc. (Palmer 1996). From this perspective, it is considered a useful source of information about behaviour differences within

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populations and among them (Ruff/Jones 1981; Fresia/Ruff/Larson 1990)

At this time we distinguish several asymmetry types which may manifest in a similar manner but arise from different causes (Palmer 1994); they may develop in the prenatal (Schultz 1937; Pande/Singh 1971), or postnatal period (Steele/Mays 1995), in childhood (Van Dusen 1939), during adolescence (Schell et al. 1985), or during adult life (Laubach/McConville 1967; Malina/Buschang 1984).

Origination and development of asymmetry is affected by specific factors. Their intensity may be *inter alia* assessed by the measure of asymmetry. In summary, these factors have been described: genetic, hormonal, environmental, biomechanical, age, sex and body weight of individual. We focused on the following of them: *environmental factors* involve stress of a different origin, e.g. malnutrition, excessive noise, cold, heat, etc., which increase asymmetry (Kieser/Groenveld/Preston 1986; Schell et al. 1985; Čuk/Leben-Seljak/Štefančič 2001). The degree of asymmetry reflects also the *biomechanical impacts* (Graham/Freeman/Emlen 1993) – the force which affected the right or left side. Then, the localization of asymmetry on particular bones indicates the type of the used force. The greater the load affecting long bones, the more asymmetrical their morphology results (Čuk/Leben-Seljak/Štefančič 2001; Schell et al. 1985; Ruff/Jones 1981). The *age of the individual* may be another factor. The dependence of the asymmetry rate on age has been confirmed by B. Škvařilová (1999), Helmkamp/Falk (1990), Ruff/Jones (1981) but not confirmed by Roy/Ruff/Plato (1994) and J.H. Plochocki (2002). The *sex of the individual* is also taken into account. Here again, the conclusions are contradictory about the role of this factor in asymmetry development. A list of authors who did not find sex differences in the degree of asymmetry include B. Škvařilová (1999), Steel/Mays (1995), Schell et al. (1985), Roy/Ruff/Plato (1994). In some studies the samples were not divided according to sex (Čuk/Leben-Seljak/Štefančič 2001; Roy/Ruff/Plato 1994). Other studies demonstrate that this factor also contributes to asymmetry (Feik/Thomas/Clement 1996; Mays/Steele/Ford 1999; Lazenby 2002). Seemingly, *body weight* has no impact on asymmetry considering that the lower limbs are under a higher load but exhibit a less degree of asymmetry than the upper limbs (Schell et al. 1985).

The basic asymmetry types are directional asymmetry, fluctuating asymmetry, antisymmetry, and cross-asymmetry. *Directional asymmetry (DA)* is a type of bilateral asymmetry where in the whole sample a statistically significant difference exists between sides and the side that is larger is generally the same. The mean of values [right side (R) – left side (L)] differs from zero (see Figure 1b) (Van Valen 1962; Palmer 1994). *Fluctuating asymmetry (FA)* is a type of bilateral asymmetry where the mean value (R - L) is zero all variations are normally distributed about the mean (see Figure 1a). It may be assessed only if DA or antisymmetry are absent (Palmer 1994). *Antisymmetry (AS)* is the presence of bilateral variation where a statistically significant difference exists between sides, but the side that is larger varies among individulas. The mean (R - L) is zero, and the distribution of variations around this mean is platykurtic or bimodal (see Figure 1c) (Van Valen 1962).

Cross-asymmetry has been described as the phenomenon when in one individual the right upper limb is more developed together with the left lower limb, or *vice versa.* In general, the right-handers have a better developed right upper limb and left lower limb (Ruff/Jones 1981). According to Čuk/Leben-Seljak/Štefančič (2001), about 90% of people have a more developed right upper limb, and about 55-75% people have a more robust left lower limb. The dominant lower limb has a more robust structure of the tibia, and it is on the opposite side to the dominant upper limb. According to B.E. Ingelmark (1946) 85% of right-handers have a longer left lower limb while 85% of left-handers have a longer right lower limb. Disregarding handedness (see below), the left lower limb may be more robust because its

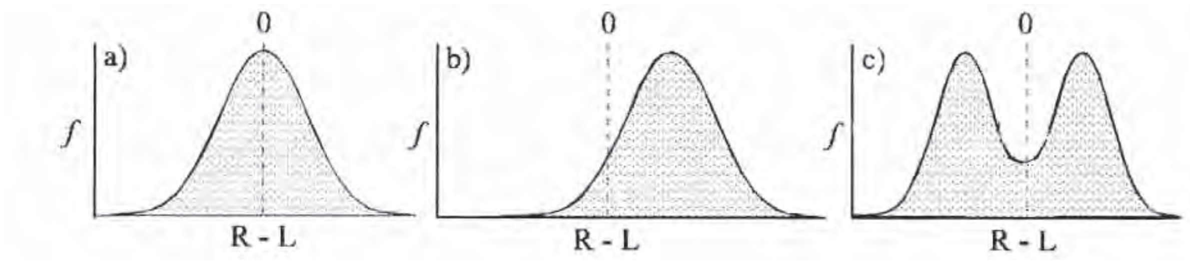


Figure 1. Three common distributions of the R - L difference in bilateral organisms: a) fluctuating asymmetry; b) directional asymmetry; c) antisymmetry (Palmer 1994).

function is to support while the right lower limb is used for other functions (e.g. kicking) (Singh 1970; Plato/Fox/Garruto 1985; Macho 1991; Čuk/Leben-Seljak/Štefančič 2001). In conjunction with asymmetry of the limbs we encounter the term *'handedness'*, which means a preference for one (right or left) hand for certain manipulations. Handedness exerts an impact on the asymmetry of the long bones of the limbs: they are longer and larger on the dominant side. The general trend is a preference for the right hand (Steele/Mays 1995; Čuk/Leben-Seljak/Štefančič 2001).

Investigations have been carried out both on skeletal collections (Čuk/Leben-Seljak/Štefančič 2001; Albert/Greene 1999; Mays/Steele/Ford 1999; Plochocki 2002; Steele/Mays 1995; Stock/Pfeiffer 2001; Stirland 1993) and on clinical material (most frequently body dimensions, dermatoglyphs, X-ray prints) (Schell et al. 1985; Škvařilová 1999; Plato/Wood/Norris 1980; Laubach/McConville 1967; Fields et al. 1995; Roy/Ruff/Plato 1994; Macho 1991; Little/Buschang/Malina 2002). As a rule, the results show that bilateral asymmetry is more expressed in the upper limbs. On average, the long bones of the right upper limb are 1-3% longer, and 2-4% heavier than the long bones of the left side. The most asymmetric bone is the humerus by which we can probably assess the preference, and therefore also the dominance of one or the other upper limb (Čuk/Leben-Seljak/Štefančič 2001). As a rule, the left lower limb is more robust (the results vary with regard to the length dimensions) (Latimer/Lowrance 1965; Ruff 1992; Macho 1991). According to Čuk/Leben-Seljak/Štefančič (2001), the lower limb bones, especially the femur, are longer and heavier on average.

The diaphyseal widths and circumferences are more asymmetric than the longest lengths of the long bones. The proximal humeral epiphyses are more asymmetric than the distal ones, and this relation is reversed in the forearm bones; therefore, the wrist and shoulder joints are evidently more 'stressed' than the elbow (Čuk/Leben-Seljak/Štefančič 2001).

The upper and lower limb length as a whole is less asymmetric than the length of particular segments of the relevant limbs (Jurowska 1972; Škvařilová 1999).

According to Mays/Steele/Ford (1999), the right clavicle is shorter and more robust in most individuals, especially in adults. They did not find any deviations in its curvature or in its vascularization. As a rule, the muscle and ligament insertion sites were larger on the right side.

2. Material

Two osteological collections were used to represent medieval and recent population.

A sample of medieval population dated to the Great Moravia came from two archaeological sites Mikulčice-Kostelisko (sub-castle of the centre) and Prušánky (hinterland). Only adult individuals with ascertained sex, estimated age at the time of death and in good conditions of preservation and completness were considered (Dobisíková 1999). On this basis, 78 males and 132 females skeletons from the Mikulčice-Kostelisko necropolis and 66 males with 69 females skeletons from the Prušánky necropolis were selected.

We used the so called 'Pachner's collection' as a comparative sample of recent population. The uniqueness of this collection is that it consists of more than 300 postcranial skeletons with following documentation: name, sex, age, height, and autopsy year of individuals. The collection came from the1930's and involves Czech inhabitants from socially less situated ranks. The sex distribution is equal (Pachner 1937). From this collection 143 males and 157 females were selected.

The bones of the lower limb (femur, tibia, fibula), and the bones of the upper limb (humerus, radius, ulna, scapula, clavicula) were used for the analysis. Bones with pathologic findings were not processed.

3. Methods

All age categories of the adult individuals were assessed together. Both sexes were evaluated separately.

In asymmetry assessment it is desirable to have dimensions of both left and right bones and so only cases where the individual's paired bones remained preserved were included. For assessment of the difference between sexes or populations we also included cases where only one of the individual's paired bone remained preserved.

The defined metric dimensions (Martin/Saller 1957; Velemínský 2000) were measured – 21 linear dimensions on the upper limb, and 27 linear and circumferential measures on the lower limb (for list of dimension see Table 1).

Apart from basic statistical characteristics, the testing of repeatability was done. Both left and right bones of 16 individuals were remeasured (Steele/Mays 1995; Mays/Steele/Ford 1999) and the interobserver error was calculated using the reliability coefficient of the particular measurements and of asymmetry scores (Fields et al. 1995). The systematic error was assessed using the paired t-test. The ANOVA test was used to rule out the FA being caused by measurement error (Little/Buschang/Malina 2002; Roy/Ruff/Plato 1994).

The comparison of recent versus medieval population and assessment of sexual dimorphism was analysed using the t-test for independent samples (confidence values: p-value ≤ 0, 05).

Normal distribution of the difference between the right and left side was expressed graphically and also presence of antisymmetry (bimodal, or platykurtic curve) was excluded.

The presence and degree of DA was determined using the paired t-test. Dimensions with significant differences (p-value ≤ 0, 05) between the right, and the left side were considered to be directionally asymmetric. On the remaining dimensions where neither DA, nor AS was manifested we tested for the presence of FA. We used the formulas according to Palmer/Strobeck (1986), specifically the values FA1, FA2, FA4, and FA6. The values FA1 and FA2 yield the information about unsigned (absolute) asymmetry – if and by how much on average the magnitudes R and L differ. The values FA4 and FA6 provide information about signed asymmetry – the direction of the asymmetry. FA2 and FA6 are not biased by size-dependence of the right-left difference (for the formulas see Table 5).

In order to assess cross-asymmetry the sample of individuals was divided into four groups (according to the longest humerus length): hypothetical 'right-handers' (longer right humerus), 'left-handers' (longer left humerus), and ambidextrous (both bones equally long) (Čuk/Leben-Seljak/Štefančič 2001; Steele/Mays 1995). In subsequent processing, the percentage of hypothetic right-handers with longer left lower limb bones, or left-handers with longer right lower limb bones were compared. For this analysis the maximum humerus length, the maximum length of femur as well as the physiological length of the femur, the overall and medial tibia length, and the maximum fibula length were used.

The software STATISTICA for Windows version 5.0 and Microsoft Excel 1997 was used to carry out the calculations.

4. Results

No statistically significant differences between repeated measurements were shown in the measurement accuracy test by reliability calculation (reliability coefficient), systematic error testing, and the ANOVA test. The reliability coefficient did not drop below 0.8, thus, all measurements were meaningful and the variability between traits was not caused by a measurement error. But the repeatability of particular measurements is not an adequate guide to the repeatability of asymmetry scores derived from it – because it depends both on measurement error and on the size of the difference between sides (Fields et al. 1995; Mays 2002). In particular, in FA assessment differences between sides are generally small, so the contribution made by measurement errors in asymmetry scores is larger than is the case for raw measurements. Measurement error tends to have a randomizing effect on the data. Hence in our study FA (the greater the measurement error, the greater the impact on the estimate of the subtle asymmetries; Palmer 1994) was assessed only on dimensions, where no measurement error was noted in asymmetry scores.

Within the scope of sexual dimorphism monitoring males from recent population had all dimensions statistically significantly greater than females. In the Great Moravian population it was the same, except for the left humeral head and the length of the right ulna.

Tables 1 and 2 give the data of a population comparison using the metric characteristics of the upper and lower limb bones. When considering the upper limb bones, it was found out that males from both populations differed in 25% of monitored traits. Males from the Great Moravian population exhibited greater length dimensions of the upper limb long bones whereas males from the recent population had a significantly greater vertical diameter of the left humerus head, and sagittal diameter of the radius diaphysis. The size differences between females of these populations were more frequent than between males (45% of monitored traits). For medieval females greater

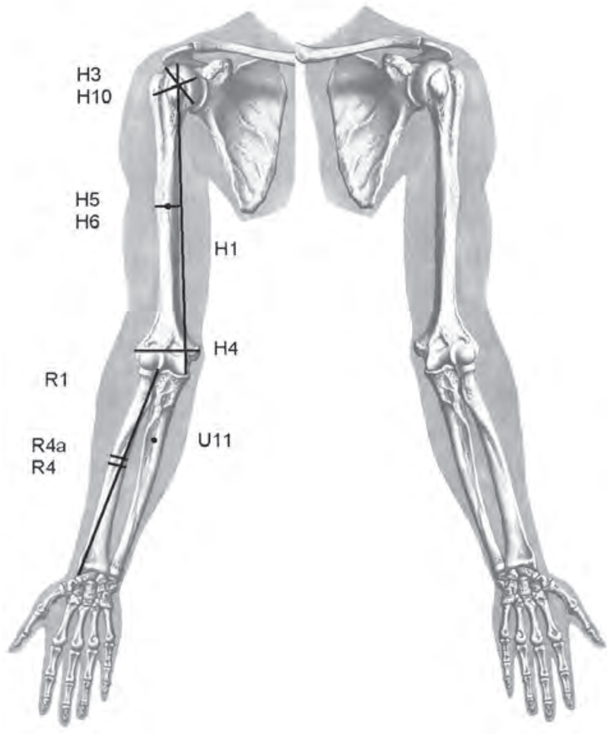


Figure 2. Depiction of the dimensions of upper limb bones in which DA was observed. Great Moravian Males.

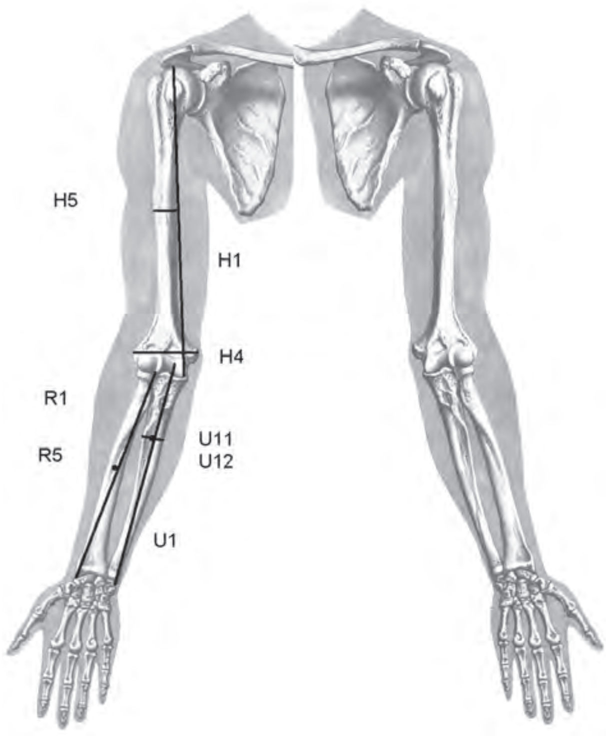
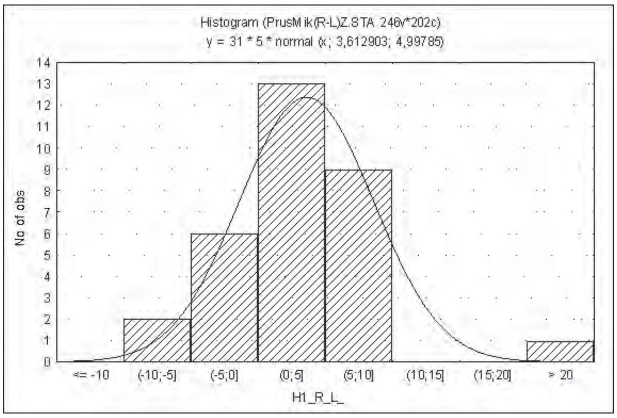
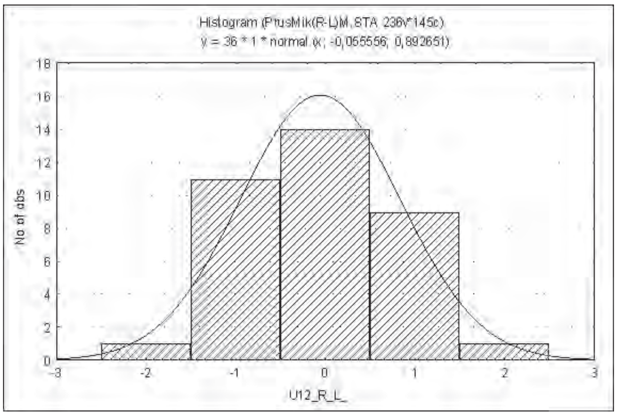


Figure 3. Depiction of the dimensions of upper limb bones in which DA was observed. Great Moravian Females.



Graph 1. Histogram of R - L difference distribution (females, Great Moravian population, maximum length of the humerus).



Graph 2. Histogram of R - L difference distribution (males, Great Moravian population, width of the diaphysis of the ulna).

length dimension values of forearm bones were characteristic. Females from the recent population had higher values of most humeral, and clavicular diameters, and of forearm bones width parameters.

The situation is similar with lower limb dimensions. Females from both populations differed more than males (in 43% compared to males in 27% of measured traits). All statistically significant as well as insignificant differences of the lower limb bones were greater in recent than in medieval females. In males, significant differences became evident on the lower limb bones especially on the femoral diaphysis and tibial length but it varied according to the population. Comparison of the average femoral and tibial dimension values in males indicated, that medieval males were greater in length dimensions; recent males mostly in the dimensions of diaphyses and epiphyses.

The graphical analysis showed that the R - L difference was normal distributed and therefore antisymmetry did not manifest itself in any trait (for example see Graph 1 and 2).

DA was more frequent in both populations on bones of the upper limb than on bones of the lower limb. Figures 2-5 illustrate the dimension in which DA was observed in the both population.

In the recent population (Tables 3 and 4) DA was present in almost all upper limb bones studied (in 81% of metric traits in females and 67% in males) and with the exception of the clavicular length it was always in favour of the right side. It was most expressed on the humerus (in all dimensions) and on the maximum lengths of forearm bones, and least on the dimensions of the scapula. The clavicle was shorter and more robust on the right side in most individuals. The differences between sexes were not very expressive; however, greater differences between average dimension values were noted in females.

DA in the lower limb bones of recent population was recorded only in the size characteristics of the femur; it was not manifested in the tibia and fibula. DA was pronounced on 47% of the dimensions in females, and on 33% of the dimensions in males. The DA of the length dimensions and the diaphyseal dimensions was directed to the left in both sexes, in epiphyseal dimensions it was directed to the right side. In males and females, left side DA on the femur was recorded in the physiological length and in most sagittal diaphyseal diameters, in females moreover in the diaphyseal circumference, and in some transversal diaphyseal diameters. Right side DA on the femur was manifested on the lower epicondylar width in males, on the upper width of the epiphysis in females.

In the Great Moravian population (Tables 5 and 6) DA of the upper limb bones was recorded less (in 38% of metric traits in females and 48% in males), especially in the length dimensions of all the long bones, except for the clavicle. With regard to sexual dimorphism there were some differences. On the humerus and radius asymmetry was manifested in males almost in all dimensions, in females only in the maximum lengths and also on certain diaphyseal diameters of these bones. On the contrary, the ulna was more asymmetric in females (DA was seen in all dimensions); in males it only involved the sagittal diaphyseal dimension.

In the lower limb dimensions the presence DA was recorded more frequently than in the recent population, and it was always directed to the left. It was manifested on the femur in 53% of traits in males, in 33% in females; on the tibia in both sexes in 18% of traits. On the femur, in males DA was recorded in the length dimensions, in most diaphyseal diameters, and also in the diaphyseal circumference. In females it was less frequent; it was observed in the physiological length, in certain transversal diameters, and in the lower sagittal diaphyseal diameter. The most statistically significant deviations were in the transversal epiphyseal diameter. On the tibia, DA was manifested in both sexes in the overall tibia length, in males in the diaphyseal circumference, and in females in the medial tibia length.

Neither population, with regard to the upper limb, had more asymmetric widths of the long bone diaphysis in comparison with their length dimensions; this also applies to the comparison of proximal and distal humeral epiphyses

The presence of FA (Table 7 and 8) on the bones of the upper limb was very low; on the lower limb FA was manifested much more frequently in both sexes, but even there its values were very low. FA attained the highest values in the length dimensions (FA1, FA4) but if the FA values were related to the size of the measured trait it was almost negligible (FA2, FA6). Recent population, where FA could be seen especially in the scapula dimensions, reached higher FA values in both upper and lower limb bones than the medieval population. Higher FA values of

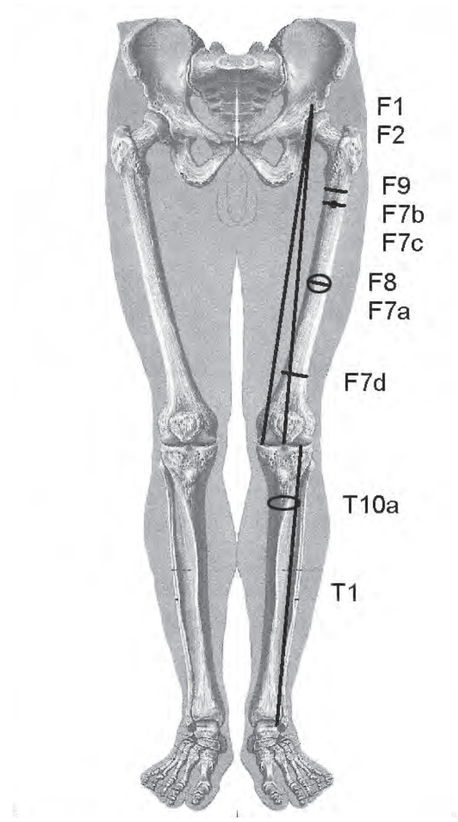


Figure 4. Depiction of the dimensions of lower limb bones in which DA was observed. Great Moravian Males.

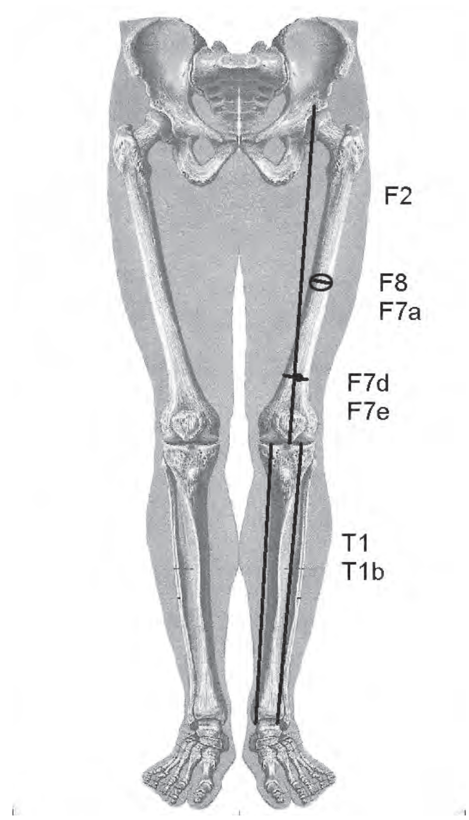


Figure 5. Depiction of the dimensions of lower limb bones in which DA was observed. Great Moravian Females.

the upper limb had the Great Moravian population in the clavicle, and in the maximal length of the ulna. In both populations lower limb FA reached the highest values in lengths and in circumferential dimensions in tibia and on upper epiphysis of femur.

All the long bones of the right upper limb (with the exception of ulna in Great Moravian males) were significantly longer in most individuals from both populations. The same result was in the case of left femora but these findings cannot be interpreted as cross-asymmetry because they do not tell us whether individuals with longer long bones of the right upper limb had longer long bones of the left lower limb at the same time. In the Great Moravian population, subsequent analysis did not confirm cross-asymmetry either in males or females who had a longer right humerus. Individuals with a longer left humerus could not be assessed because of the low number of preserved bones. In the recent population, only tibia and fibula lengths in males indicated cross-asymmetry.

In both populations, the percentage of individuals with a longer right/left humerus, or with both humeri equally long, corresponds to the distribution of right-handers and left-handers, and ambidextrous individuals in the recent European population.

5. Discussion

If asymmetry is considered – *inter alia* – indicative of non specific stress affecting the organism, it could be indirectly connected also with the social structure of the society, the quality of the living conditions (nutrition, individual health, degree of stress of different origin, etc. (e.g. Graham/Freeman/Emlen 1993; Livshits et al. 1998), and also with influences from biomechanical stress (Roy/Ruff/Plato 1994), or with the activities carried out as well as with a preference for the right or left side of the body (Steele/Mays 1995).

With regard to sexual dimorphism, males and females from both populations differed markedly in most assessed dimensions. It was noticeable that in the Mikulčice-Kostelisko necropolis no sexual differences were found in several dimensions. This involves the maximum length of the right ulna, and the maximum transversal, and vertical dimensions on the head of the left humerus. P. Velemínský (2000) came to the same conclusion about this necropolis. Similar results were also available from other Great Moravian burial-grounds – Josefov (Stránská et al. 2002), and Bulhary (Dobisíková et al. 2003). According to the publication of Černý/Komenda (1982), quite reliable sex identification can be done from the humeral head, which contradicts our results. It is possible that this method cannot be applied to the Mikulce's Great Moravian population. Our findings on the recent population comply with the work of M. Černý (1971). The most significant sexual differences were recorded in head diameters, the circumferences and diameters of the middle of the diaphysis, and in the maximum femur length. On the tibia, in agreement with the work of Leopold/Minuth/Krüger (1986) and G. Singh/S. Singh/S.P. Singh (1975), the most expressed sexual dimorphism was manifested on the epiphyses, in bone length, and in all circumferential dimensions. The differences in the average dimension values of females and males proved that sexual dimorphism was more expressed in the Great Moravian population. A high degree of sexual dimorphism is considered to be a sign of good health, and low stress (Lazenby 2002). If so, it can be presumed that the medieval population was submitted to lower environmental stress than the sample of the recent population.

Comparing the size characteristics of single dimensions using the t-test for independent samples, certain differences between the two populations were found**.** Size differences were encountered more frequently in females than in males. The upper limb long bones of males from the Great Moravian population had greater length dimensions. This could be affected by the fact that individuals from the recent population had in general a gracile figure (they came from a lower social status, Pachner 1937). In comparison with the medieval males, recent males had a shorter but more robust femur and tibia; on the upper limb they had only a greater vertical diameter of the left humeral head. According to our investigations, medieval females had higher length dimensions of the forearm bones. Females from the recent population had significantly higher values of most dimensions of the humerus and clavicle, and they also had greater values of the forearm bones width parameters. In the lower limb they exibited greater dimensions of the diaphyses of the studied bones. This was a surprising result regarding the supposed gracility as a consequence of the lower life standard of 'Pachner's collection' individuals. Conversely, this might relate to the secular trend for increased stature through time.

The scapula, clavicle, and fibula of the populations do not show any statistically significant differences. However, in the case of the Great Moravian population group the result for the scapula and fibula may be affected by the low number of observations.

For the comparison of the cemeteries Mikulčice-Kostelisko and Prušánky with other Great Moravian cemeteries, Josefov (Stránská et al. 2002), Břeclav-Pohansko (Drozdová 1997), and Bulhary (Dobisíková et al. 2003) were chosen. We could make a general conclusion about the *upper limb bones* that the greatest metric characteristics were seen in Pohansko, and in the Prušánky burial-place (above all in males), whereas they were least in the Mikulčice-Kostelisko cemetery, which could be partially explained by the shortage of males in this burial-ground. In the case of *lower limb bones,* Prušánky and Bulhary were about average but when females femur robustness was concerned they were among the greatest. Individuals from the Mikulčice-Kostelisko cemetery had the most gracile and shortest lower limb bones; their dimensions most resemble those of Josefov.

We can confirm the assumption based on prior investigations (e.g. Čuk/Leben-Seljak/Štefančič 2001; Škvařilová 1999; Steele/Mays 1995), that DA should be present in most bones of the upper limb, and that it is most expressed in the humerus, namely in favour of the right side. Velemínký (2000) also recorded asymmetry of the upper limb bones in favour of the right side in the Great Moravian population.

In most of the studied upper limb bones DA was shown especially on their maximum lengths, and irregularly on the diaphyseal diameters. In the medieval population, DA appeared less than in the recent population (Pearson Chi-square value=7.4; p=0.006). As the recent sample was of a lower socially class, a certain non-specific stress could be assumed because asymmetry could also be caused by such an overload (long-lasting unsuitable living conditions, insufficient nutrition, or other stresses from the environment; *inter alia:* Livshits/Kobyliansky 1987; Graham/Freeman/Emlen 1993). Again, Steele/Mays (1995) presumed that the DA of limb bones develops as a consequence of greater mechanical stress affecting the dominant limb, and that it increases with age (prolonged stress). It is possible that in individuals from the recent population, one (the dominant) upper limb was submitted to greater stress.

Earlier studies (e.g. Mays/Steele/Ford 1999; Huggare/Houghton 1995) showed that the right clavicle is shorter and more robust in most individuals. Our study agreed with these results in the case of recent males and females but in the medieval population we did not confirm this assumption. This phenomenon is explained by the assumption that clavicle growth of the dominant limb is inhibited due to the greater muscle development in this area (Mays/Steele/Ford 1999).

Compared to earlier investigations (Steele/Mays 1995; Mays/Steele/Ford 1999; Čuk/Leben-Seljak/Štefančič 2001) on the handedness, it was found that in the recent population, there were about 81% of right-handers. Therefore, the majority of right-handers had a shorter and more robust right clavicle, and primarily longer and slightly more robust long bones of their right upper limb. The differences were most expressed on the humerus.

In accordance with the results of most studies (*inter alia:* Škvařilová 1999; Čuk/Leben-Seljak/Štefančič 2001) DA in the lower limb appeared much less than in the upper limb, and this applied to both populations. In the majority of cases, it was directed to the left, and thus confirmed the greater robustness of the left lower limb in connection with stress affecting it during life (Čuk/Leben-Seljak/Štefančič 2001). In the recent sample DA was shown only in the femur, in the medieval sample it appeared also in certain dimensions of the tibia. DA was not registered on the fibula.

In earlier studies (Ruff 1992; Latimer/Lowrance 1965; Singh 1970) asymmetry was usually not found in the bone lengths but only in their robustness. To a certain extent, this agrees with our results: DA was found rather in the dimensions on the diaphyses than on their lengths. According to Čuk/Leben-Seljak/Štefančič (2001), this might be due to the fact that the longitudinal bone growth is completed between the 18th and 25th year of age, but the width growth of the bones continues during the rest of life.

Individuals from the Great Moravian population exhibited little more DA in the lengths of lower limb bones (namely the tibia and femur), but there was no significant difference (Pearson Chi-square value=1.20; p=0.274). The left femur had a more robust diaphysis in both populations (similar to Čuk/Leben-Seljak/Štefančič 2001; Ruff/Hayes 1983; Macho 1991; Velemínský 2000). According to many authors (e.g. Ruff/Hayes 1983), the reason consisted mainly of the stress resulting from the supporting function of the lower limb. It is interesting, however, that femur of recent females was little more asymmetric than medieval females population (47% of traits in recent compared to 33% of traits of medieval females), whereas lower limb of medieval males was little more asymmetric than in recent males (38% of traits in medieval compared to 19% of traits of recent males). In addition, recent males – in contrast to the medieval males – had less sagittal flattening of left femoral diaphyses than of the right. Conversely, Great Moravian males had left femur wider in the transversal direction. The epiphyseal femoral dimensions showed DA in favour of the right side only in the recent population, although the right side was non-significantly greater in medieval population as well. According to Čuk/Leben-Seljak/Štefančič (2001) this might be the result of stress affecting the knee (and the hip) of the right lower limb which has not any supporting function.

The more robust diaphysis of the left tibia in medieval males might be connected with the dominance expression of the left lower limb (on the opposite side to that of the dominant upper limb; Čuk/Leben-Seljak/Štefančič 2001).

If the sexual dimorphism was considered, different conclusions were recorded as in earlier studies. Some investigators did not find differences between the degree of asymmetry and the sexes (e.g. Škvařilová 1999; Steel/Mays 1995). According to other studies, this factor contributes to asymmetry (Feik/Thomas/Clement 1996; Mays/Steele/Ford 1999; Schultz 1937). Our investigations suggested that the differences were not so substantial.

In the recent population DA occurred more often in females in accordance with the study of Schultz (1937; in 41% of traits in males, in 52.3% in females). Conversely, in the Great Moravian population DA occurred more often in males as was confirmed by the investigations of Schell et al. (1985), or Lazenby (2002) who suggested that females are better able to buffer detrimental effects of environmental stress. In recent females, DA occurred in most dimensions of the upper limb (in 81% of traits). In the Great Moravian population DA was manifested in 48% of traits in males (mostly on the humerus); in females it occurred in 38% of traits (mostly on the ulna). P. Velemínský (2000) similarly confirms greater asymmetry of femur in males from the Mikulčice-Kostelisko necropolis while Ruff/Hayes (1983) found more asymmetric femora in females. Like our study, C.B. Ruff (1992) did not register sexual differences in femur length asymmetry.

Based on these observations, it could not be unequivocally established if males or females were in general 'more asymmetric', neither could the impact rate of this factor regarding DA on the upper limb be defined.

For the assessment of **fluctuating asymmetry (FA)** it was chosen the procedure published by Palmer/Strobeck (1986). FA evaluation is often criticised if it was present prior to exclusion of antisymmetry or DA. Unfortunately, a comparison with other studies is not possible because FA has not been monitored so far in the bones of analogous populations. When studying FA, it is very important to remove or qualify the measurement error. In this study the measurement of the bones of 16 individuals was repeated (Steele/Mays 1995, Mays/Steele/Ford 1999). FA was assessed only in dimensions where no measurement error of raw measurement and also in asymmetry scores was recorded (Fields et al. 1995; Mays 2002). Yet, our results agreed with a study of the upper limb performed on clinical material (Škvařilová 1999) which showed that DA occurred above all on the bones of the upper limb. In our study FA values were very low, and if related to the size of the measured trait it was almost negligible. In spite of the low values, in the recent population higher values of FA were noted, particularly in the scapula. In the medieval population, relatively higher FA values appeared in the clavicle. Possible explanation was that DA appears often in this dimension (Mays/Steele/Ford 1999), but this was not confirmed in our sample. Higher values were also observed on the ulna length but also in this case, this is a dimension where DA occurs very often, according to our results. On the other hand, in clinical material, Škvařilová (1999) assessed the presence of FA on the forearm length. She registered FA of the width of the distal epiphysis of the humerus. We did not find similar results in either population.

With regard to the lower limb, the highest variance values (FA4), and absolute FA deviations (FA1) were registered in the length dimensions, lower values were registered in the diaphyseal and epiphyseal metric characteristics. But as soon as the FA size was related to the trait size (FA2 and FA6) the result was negligible, as in the upper limb.

The FA of limb bones reached higher values in the recent population than in the medieval sample. Some studies connect higher FA with increased environmental stress (Van Valen 1962; Palmer 1994; Zakharov/Graham 1992). This might also confirm the results of sexual dimorphism where more expressed differences were found between sexes in the medieval population – and a high degree of sexual dimorphism is considered to be a sign of good health, and low environmental stress (Lazenby 2002). Accordingly, the recent sample (lower social class) was subject to higher environmental stress than the group from Great Moravian period.

The length dimensions of the long bones of the upper limb (humerus + radius) as well as the lower limb (femur + tibia) were summarized to compare the maximum lengths of limbs and their asymmetry. The limb lengths asymmetry was similarly assessed inter alia by Ingelmark (1946). The relevant number of observations was so low, however, that we could not proceed to any assessment.

In general, right-handers have a better developed right upper limb, together with a better developed left lower limb (Ruff/Jones 1981; Siniarska/Sarna 1980). Therefore, all groups were divided according to their maximum humeral length into hypothetical 'right-handers' (longer right humerus), 'left-handers' (longer left humerus), and into ambidextrous individuals (both humeri of equal length) (*inter alia* according to Čuk/Leben-Seljak/Štefančič 2001; Steele/Mays 1995). The results for the Great Moravian population were: 95.8% of males had a longer right humerus, 4.2% had a longer left humerus, and any case of equally long humeri was found. In females from Great Moravia, 73.3% had a longer right humerus, 20% a longer left humerus, and 6.7% had both bones equally long.

In the recent population results indicated that 81.2% of males had a longer right humerus, 12% had a longer left humerus, and 6.8% of males had both humeri equally long. In recent females, the results were similar: 81.6% of females had a longer right humerus and 13.6% of females had a longer left humerus while 4.8% of females had both humeri equally long. Our findings correspond with the following investigations: Annet/Kilshaw (1983) (82% right-handers, 15% left-handers, and 3% of ambidextrous individuals), Steele/Mays (1995) (81% right-handers, 16% left-handers, and 3 % of ambidextrous individuals), Čuk/Leben-Seljak/Štefančič (2001) (87% longer right humerus, 10% longer left humerus, and 3% both bones equally long).

In subsequent analyses, the percentage of hypothetic 'right-handers' and 'left-handers' with longer left/right lower limb bones [e.g. according to Ingelmark (1946) 85% of right-handed individuals had a longer left lower limb while 85% left-handers had a longer right lower limb]. Among males and females from the Great Moravian population who had longer humeri on their right upper limb a greater percentage of individuals with a longer right femur, tibia, and fibula was found. Here, cross-asymmetry also was not statisticaly confirmed. The results on hypothetic left-handed individuals from the Great Moravian population cannot be interpreted because of the low number of preserved bones.

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Table 1. Results obtained by comparing males from a medieval, and a recent population – independent t-test .
Expanatory notes: averages are specified in mm; t-value – value of the t-test; df – degrees of freedom; N –number of dimensions; Std.Dev. – standard deviation; p – test level attained; significance levels: * = 5%, ** = 1%, *** = 0.1%

	Measurements	Abbr.		Recent	Medieval	Recent	Medieval		Recent	Medieval				
				N	N	Mean		df	Std.Dev.	Std.Dev.	t-value	p	Signf.	Larger
SCAPULA	anatomical width	Sc1	sin	95	1	162.2	149.0	94	9.2	0.0	1.425	0.158		
			dx	92	0	161.4		90	8.9					
	anatomical length	Sc2	sin	121	3	105.0	111.0	122	6.4	1.0	-1.595	0.113		
			dx	116	4	103.9	109.3	118	5.7	3.4	-1.841	0.068		
	length of the margo materalis	Sc3	sin	119	1	138.6	139.0	118	8.1	0.0	-0.049	0.961		
			dx	117	7	137.6	142.1	122	8.6	12.3	-1.321	0.189		
CLAVICULA	maximum clavicle length	Cl1	sin	106	23	151.0	150.0	127	7.8	11.2	0.530	0.597		
			dx	110	17	149.0	148.8	125	8.2	11.4	0.074	0.941		
	vertical diameter	Cl4	sin	116	47	11.1	11.1	161	1.3	1.3	0.291	0.771		
			dx	121	48	11.3	11.5	167	1.5	1.5	-0.764	0.446		
	sagittal diameter	Cl5	sin	116	47	12.6	12.7	161	1.4	1.2	-0.393	0.695		
			dx	121	48	12.9	12.8	167	1.4	1.5	0.453	0.651		
HUMERUS	maximum length of the humerus	H1	sin	128	39	322.6	326.2	165	17.4	17.5	-1.133	0.259		
			dx	121	37	326.0	334.1	156	17.0	14.8	-2.620	0.010	*	med
	width of the upper epiphysis	H3	sin	128	21	50.5	50.0	147	2.4	2.5	0.810	0.419		
			dx	121	19	51.5	51.5	138	2.4	2.9	0.105	0.917		
	width of the lower epiphysis	H4	sin	127	29	61.7	62.2	154	3.8	5.1	-0.600	0.550		
			dx	123	35	62.3	63.3	156	3.9	3.8	-1.314	0.191		
	maximum diameter of the middle of the diaphysis	H5	sin	129	78	23.3	22.8	205	2.0	1.8	1.716	0.088		
			dx	123	75	23.8	23.6	196	2.1	2.0	0.793	0.429		
	minimum diameter of the middle of the diaphysis	H6	sin	129	79	18.6	18.5	206	1.7	1.5	0.684	0.495		
			dx	123	76	19.0	18.7	197	1.7	1.7	1.088	0.278		
	maximum transverse diameter of the head	H9	sin	127	13	44.3	43.2	138	2.1	3.9	1.622	0.107		
			dx	116	5	44.8	44.2	119	2.3	2.6	0.529	0.598		
	maximum vertical diameter of the head	H10	sin	128	24	48.0	45.4	150	2.5	6.3	3.422	0.001	**	rec
			dx	121	19	48.6	47.9	138	2.3	6.0	0.807	0.421		

	Measurements	Abbr.		Recent	Medieval	Recent	Medieval		Recent	Medieval				
				N	N	Mean		df	Std.Dev.	Std.Dev.	t-value	p	Signf.	Larger
ULNA	maximum length of the ulna	U1	sin	109	18	256.1	269.3	125	13.1	20.5	-3.616	0.000	***	med
			dx	107	28	257.3	267.9	133	13.0	25.2	-3.094	0.002	**	med
	sagittal diameter of the diaphysis	U11	sin	112	48	14.3	14.3	158	1.3	1.6	0.225	0.822		
			dx	107	55	14.4	14.4	160	1.4	1.6	-0.067	0.947		
	width of the diaphysis	U12	sin	112	48	17.6	17.6	158	1.4	1.8	-0.203	0.840		
			dx	107	54	17.6	17.4	159	1.5	1.8	0.896	0.371		
RADIUS	maximum length of the radius	R1	sin	103	24	237.3	246.5	125	12.0	16.8	-3.092	0.002	**	med
			dx	105	25	239.2	248.1	128	12.3	17.3	-2.977	0.003	**	med
	maximum width of the diaphysis	R4	sin	103	47	17.8	17.3	148	1.7	1.7	1.617	0.108		
			dx	107	48	18.1	17.8	153	1.8	1.4	1.178	0.241		
	width of the middle of the diaphysis	R4a	sin	104	42	16.7	16.4	144	1.5	1.6	1.146	0.254		
			dx	107	48	17.2	16.8	153	1.7	1.6	1.419	0.158		
	sagittal diameter of the diaphysis	R5	sin	103	46	12.4	12.2	147	1.1	1.2	1.091	0.277		
			dx	107	48	12.6	12.5	153	1.1	1.4	0.457	0.648		
	sagittal diameter of the middle of the diaphysis	R5a	sin	104	41	12.7	12.2	143	1.1	0.9	2.371	0.019	*	rec
			dx	107	48	12.8	12.5	153	1.0	0.9	1.994	0.048	*	rec
FEMUR	maximum length of the femur	F1	sin	76	48	450.6	456.2	122	26.2	29.9	-1.104	0.272		
			dx	72	43	449.5	450.3	113	24.4	29.4	-0.154	0.878		
	physiological length	F2	sin	76	61	448.4	453.2	135	25.8	24.9	-1.108	0.270		
			dx	72	56	446.6	452.3	126	24.3	24.9	-1.295	0.198		
	sagittal diameter of the middle of the diaphysis	F6a	sin	78	86	28.3	28.5	162	2.5	2.8	-0.467	0.641		
			dx	72	88	28.6	28.5	158	2.5	2.8	0.440	0.661		
	transverse diameter of the middle of the diaphysis	F7a	sin	78	87	28.4	28.9	163	2.6	2.5	-1.173	0.243		
			dx	72	86	28.5	28.0	156	2.4	2.4	1.499	0.136		
	upper transverse diameter of the diaphysis	F7b	sin	78	80	30.6	32.3	156	2.8	2.7	-3.918	0.000	***	med
			dx	72	81	30.6	31.1	151	2.7	3.0	-1.258	0.210		
	upper sagittal diameter of the diaphysis	F7c	sin	78	81	28.5	27.4	157	2.4	2.7	2.649	0.009	**	rec
			dx	72	81	28.0	26.7	151	2.3	2.9	3.132	0.002	**	rec

	Measurements	Abbr.		Recent	Medieval	Recent	Medieval		Recent	Medieval				
				N	N	Mean		df	Std.Dev.	Std.Dev.	t-value	p	Signf.	Larger
FEMUR	lower transverse diameter of the diaphysis	F7d	sin	78	72	35.6	35.5	148	4.0	4.2	0.192	0.848		
			dx	72	71	35.7	34.6	141	4.1	3.9	1.544	0.125		
	lower sagittal diameter of the diaphysis	F7e	sin	78	73	31.5	30.7	149	3.2	2.8	1.767	0.079		
			dx	72	71	31.0	30.7	141	2.9	2.5	0.595	0.553		
	circumference of the middle of the diaphysis	F8	sin	78	67	86.8	89.6	143	6.3	5.9	-2.793	0.006	**	med
			dx	72	67	87.1	88.7	137	5.7	5.7	-1.616	0.108		
	subtrochanteric transverse diameter of the diaph.	F9	sin	78	90	33.3	34.5	166	2.7	2.8	-2.753	0.007	**	med
			dx	72	88	33.7	33.5	158	2.6	2.7	0.412	0.681		
	subtrochanteric sagittal diameter of the diaphysis	F10	sin	78	89	28.7	27.8	165	2.5	2.9	2.083	0.039	*	rec
			dx	72	88	28.6	27.4	158	2.2	2.2	3.395	0.001	**	rec
	upper widht of the epiphysis	F13	sin	77	55	101.3	100.2	130	6.9	7.3	0.925	0.357		
			dx	72	43	101.8	100.1	113	5.8	7.9	1.308	0.194		
	vertical diameter of the head	F18	sin	76	44	48.5	48.8	118	2.8	2.3	-0.716	0.476		
			dx	72	43	48.8	48.1	113	2.6	2.9	1.240	0.217		
	transverse diameter of the head	F19	sin	76	39	48.2	48.3	113	2.7	2.4	-0.188	0.852		
			dx	72	37	48.4	48.3	107	2.6	3.0	0.191	0.849		
	epicondylar width	F21	sin	76	18	82.1	82.8	92	4.4	5.0	-0.548	0.585		
			dx	72	18	82.9	82.3	88	4.5	5.8	0.487	0.628		
FIBULA	maximum length of the fibula	Fi1	sin	106	13	359.9	367.8	117	24.2	23.3	-1.111	0.269		
			dx	112	6	358.0	360.3	116	24.8	16.5	-0.227	0.820		
	overal length tibie	T1	sin	63	38	367.7	377.5	99	21.1	22.3	-2.216	0.029	*	med
			dx	67	35	371.1	374.3	100	20.6	30.4	-0.620	0.536		
	medial length	T1b	sin	61	30	358.3	372.3	89	21.3	22.3	-2.889	0.005	**	med
			dx	65	22	361.1	373.6	85	20.6	23.7	-2.367	0.020	*	med
TIBIA	maximum width of the upper epiphysis	T3	sin	61	6	75.0	76.8	65	3.1	0.8	-1.396	0.167		
			dx	65	8	75.1	75.8	71	3.4	3.7	-0.503	0.617		
	width of the lower epiphysis	T6	sin	62	20	48.8	47.8	80	3.1	3.8	1.206	0.231		
			dx	68	21	49.0	48.4	87	3.0	4.8	0.660	0.511		

	Measurements	Abbr.		Recent	Medieval	Recent	Medieval		Recent	Medieval				
				N	N	Mean		df	Std.Dev.	Std.Dev.	t-value	p	Signf.	Larger
TIBIA	minimum diameter of the middle of the diaphysis	T8	sin	67	61	29.5	29.5	126	3.0	2.5	0.035	0.972		
			dx	71	65	29.9	29.2	134	2.3	2.4	1.732	0.086		
	width of the middle of the diaphysis	T9	sin	67	61	23.0	22.3	126	2.1	2.0	1.922	0.057		
			dx	71	66	22.8	22.2	135	2.0	2.0	1.785	0.076		
	sagittal diameter in the upper foramen nutricium	T8a	sin	66	79	34.1	33.3	143	3.2	3.3	1.512	0.133		
			dx	70	77	34.2	33.4	145	2.9	3.1	1.616	0.108		
	width of the diaphysis in the upper for.nutric.	T9a	sin	66	78	25.1	23.7	142	2.2	2.3	3.637	0.000	***	rec
			dx	70	79	25.3	24.0	147	2.4	2.2	3.576	0.000	***	rec
	circumference of the middle of the diaphysis	T10	sin	67	55	80.6	80.4	120	6.0	5.3	0.197	0.844		
			dx	71	60	81.0	79.8	129	5.8	5.1	1.193	0.235		
	circumference of the diaphysis on the for.nutric.	T10a	sin	66	68	91.7	90.7	132	7.4	6.8	0.809	0.420		
			dx	70	63	92.2	90.3	131	6.7	6.7	1.695	0.093		
	minimum circumference of the diaphysis	T10b	sin	67	63	72.1	73.4	128	5.0	5.5	-1.374	0.172		
			dx	71	60	72.6	72.9	129	4.9	4.5	-0.311	0.756		

Table 2. Results obtained by comparing females from a medieval and a recent population – independent t-test (for legend see Table 1).

	Measurements	Abbr.		Recent	Medieval	Recent	Medieval		Recent	Medieval				
				N	N	Mean		df	Std.Dev.	Std.Dev.	t-value	p	Signf.	Larger
SCAPULA	anatomical width	Sc1	sin	97	1	144,8	148,0	96	9,0	0,0	-0,360	0,720		
			dx	90	3	144,8	140,0	91	9,1	1,0	0,907	0,367		
	anatomical length	Sc2	sin	122	7	96,4	93,1	127	5,4	3,1	1,597	0,113		
			dx	122	3	96,6	92,0	123	5,6	3,0	1,409	0,161		
	length of the margo materalis	Sc3	sin	118	3	125,3	130,3	119	8,5	1,5	-1,033	0,304		
			dx	122	4	126,3	127,3	124	8,6	5,3	-0,217	0,828		
CLAVICULA	maximum clavicle length	Cl1	sin	93	29	136,1	133,0	120	7,0	7,9	2,026	0,045	*	rec
			dx	92	35	135,1	130,3	125	7,0	7,8	3,359	0,001	**	rec
	vertical diameter	Cl4	sin	120	45	9,1	9,6	163	1,3	1,2	-2,208	0,029	*	med
			dx	120	44	9,2	9,5	162	1,2	1,2	-1,709	0,089		
	sagittal diameter	Cl5	sin	120	46	10,9	10,6	164	1,2	1,3	1,480	0,141		
			dx	120	44	11,4	10,7	162	1,3	1,2	3,083	0,002	**	rec
HUMERUS	maximum length of the humerus	H1	sin	133	52	297,4	291,5	183	14,9	16,9	2,323	0,021	*	rec
			dx	136	50	300,3	296,6	184	15,2	15,0	1,496	0,136		
	width of the upper epiphysis	H3	sin	133	33	44,8	43,5	164	2,5	2,3	2,697	0,008	**	rec
			dx	136	32	45,4	44,4	166	2,6	2,7	2,022	0,045	*	rec
	width of the lower epiphysis	H4	sin	133	41	54,0	54,3	172	3,1	3,0	-0,470	0,639		
			dx	137	40	54,6	54,9	175	3,3	3,1	-0,458	0,648		
	maximum diameter of the middle of the diaphysis	H5	sin	134	94	20,6	20,2	226	1,7	1,5	2,046	0,042	*	rec
			dx	137	94	21,1	20,4	229	1,7	1,8	3,191	0,002	**	rec
	minimum diameter of the middle of the diaphysis	H6	sin	134	94	16,2	15,8	226	1,3	1,3	2,240	0,026	*	rec
			dx	137	95	16,4	15,8	230	1,5	1,3	3,300	0,001	**	rec
	maximum transverse diameter of the head	H9	sin	126	20	39,1	39,1	144	2,0	2,3	-0,010	0,992		
			dx	126	18	39,3	39,0	142	2,2	1,5	0,633	0,528		
	maximum vertical diameter of the head	H10	sin	131	32	42,2	41,6	161	2,3	2,3	1,305	0,194		
			dx	131	30	42,4	41,3	159	2,5	2,6	2,114	0,036	*	rec

	Measurements	Abbr.		Recent	Medieval	Recent	Medieval		Recent	Medieval				
				N	N	Mean		df	Std.Dev.	Std.Dev.	t-value	p	Signf.	Larger
ULNA	maximum length of the ulna	U1	sin	129	32	230,8	241,3	159	11,3	10,7	-4,790	0,000	***	med
			dx	133	21	234,2	241,8	152	12,2	13,6	-2,581	0,011	*	med
	sagittal diameter of the diaphysis	U11	sin	136	59	11,8	11,6	193	1,1	1,3	1,322	0,188		
			dx	137	60	12,2	11,9	195	1,1	1,4	1,836	0,068		
	width of the diaphysis	U12	sin	136	60	14,9	14,7	194	1,3	1,6	0,871	0,385		
			dx	137	60	15,3	14,8	195	1,2	1,7	2,502	0,013	*	rec
RADIUS	maximum length of the radius	R1	sin	135	32	212,9	216,7	165	11,4	11,7	-1,678	0,095		
			dx	131	31	216,0	222,0	160	12,0	13,8	-2,449	0,015	*	med
	maximum width of the diaphysis	R4	sin	136	49	15,7	15,0	183	1,6	1,2	2,519	0,013	*	rec
			dx	135	48	15,9	15,4	181	1,5	1,6	1,970	0,050		
	width of the middle of the diaphysis	R4a	sin	136	56	14,7	14,2	190	1,4	1,4	2,264	0,025	*	rec
			dx	135	59	15,1	14,6	192	1,4	1,5	2,401	0,017	*	rec
	sagittal diameter of the diaphysis	R5	sin	136	50	10,6	10,6	184	0,8	1,1	-0,077	0,939		
			dx	135	51	10,6	10,8	184	0,8	1,3	-1,150	0,252		
	sagittal diameter of the middle of the diaphysis	R5a	sin	136	55	10,6	10,5	189	0,8	1,0	0,403	0,687		
			dx	135	57	10,7	10,6	190	1,0	1,0	0,974	0,331		
FEMUR	maximum length of the femur	F1	sin	74	74	414,1	406,5	146	22,4	27,4	1,845	0,067		
			dx	72	65	414,7	411,4	135	20,7	20,5	0,939	0,349		
	physiological length	F2	sin	74	81	410,6	408,8	153	22,4	16,7	0,577	0,565		
			dx	72	71	410,7	408,3	141	20,6	17,7	0,737	0,462		
	sagittal diameter of the middle of the diaphysis	F6a	sin	80	128	25,8	24,4	206	2,0	2,5	4,239	0,000	***	rec
			dx	77	114	26,0	24,4	189	2,1	2,3	4,614	0,000	***	rec
	transverse diameter of the middle of the diaphysis	F7a	sin	80	127	26,7	25,7	205	2,4	2,2	3,072	0,002	**	rec
			dx	77	114	26,4	25,3	189	2,2	2,1	3,251	0,001		
	upper transverse diameter of the diaphysis	F7b	sin	80	107	29,2	29,2	185	2,5	2,2	-0,159	0,874		
			dx	77	100	28,5	29,1	175	2,6	2,7	-1,471	0,143		
	upper sagittal diameter of the diaphysis	F7c	sin	80	105	25,8	23,5	183	2,2	2,5	6,387	0,000	***	rec
			dx	77	97	25,3	23,3	172	2,0	2,5	5,663	0,000	***	rec

	Measurements	Abbr.		Recent	Medieval	Recent	Medieval		Recent	Medieval				
				N	N	Mean		df	Std.Dev.	Std.Dev.	t-value	p	Signf.	Larger
FEMUR	lower transverse diameter of the diaphysis	F7d	sin	80	101	33,0	31,3	179	3,5	3,7	3,071	0,002	**	rec
			dx	77	91	32,9	30,9	166	3,7	3,4	3,788	0,000	***	rec
	lower sagittal diameter of the diaphysis	F7e	sin	80	98	28,6	26,7	176	2,2	2,5	5,471	0,000	***	rec
			dx	77	89	27,9	26,3	164	2,3	2,3	4,509	0,000	***	rec
	circumference of the middle of the diaphysis	F8	sin	81	83	80,0	78,9	162	5,9	5,4	1,252	0,212		
			dx	77	78	79,6	78,7	153	5,5	5,6	1,013	0,312		
	subtrochanteric transverse diameter of the diaph.	F9	sin	80	127	31,3	31,0	205	2,3	2,3	1,078	0,282		
			dx	75	120	31,1	30,9	193	2,5	2,5	0,539	0,591		
	subtrochanteric sagittal diameter of the diaphysis	F10	sin	80	128	26,0	23,9	206	1,9	2,2	6,918	0,000	***	rec
			dx	75	122	26,0	24,1	195	2,1	2,5	5,474	0,000	***	rec
	upper widht of the epiphysis	F13	sin	76	66	87,9	88,4	140	5,2	5,5	-0,557	0,578		
			dx	72	60	88,5	89,0	130	5,6	6,1	-0,514	0,608		
	vertical diameter of the head	F18	sin	74	56	42,8	42,5	128	2,7	2,2	0,584	0,561		
			dx	72	55	43,0	42,9	125	2,7	2,3	0,249	0,804		
	transverse diameter of the head	F19	sin	74	46	42,4	42,0	118	2,3	2,1	1,086	0,280		
			dx	70	50	42,8	42,3	118	2,4	2,1	1,195	0,234		
	epicondylar width	F21	sin	74	32	73,5	71,5	104	3,8	2,8	2,647	0,009	**	rec
			dx	72	28	74,0	72,1	98	3,7	3,1	2,486	0,015	*	rec
FIBULA	maximum length of the fibula	Fi1	sin	93	18	326,8	328,6	109	18,4	15,8	-0,396	0,693		
			dx	104	22	327,8	329,0	124	17,5	13,4	-0,328	0,744		
TIBIA	overal length tibie	T1	sin	80	47	337,9	337,2	125	17,2	18,3	0,229	0,819		
			dx	77	51	337,6	335,7	126	16,8	19,2	0,582	0,562		
	medial length	T1b	sin	78	34	327,8	333,3	110	20,6	16,8	-1,365	0,175		
			dx	74	37	328,8	329,6	109	17,0	19,1	-0,212	0,832		
	maximum width of the upper epiphysis	T3	sin	73	16	66,5	65,4	87	4,0	3,3	0,974	0,333		
			dx	69	13	67,0	66,7	80	3,6	3,0	0,248	0,805		
	width of the lower epiphysis	T6	sin	74	35	43,6	42,5	107	2,9	2,9	1,957	0,053	*	rec
			dx	69	27	44,1	41,5	94	2,7	3,6	3,800	0,000	*	rec

	Measurements	Abbr.		Recent	Medieval	Recent	Medieval		Recent	Medieval				
				N	N	Mean		df	Std.Dev.	Std.Dev.	t-value	p	Signf.	Larger
TIBIA	minimum diameter of the middle of the diaphysis	T8	sin	86	75	26,6	26,7	159	2,3	2,2	-0,038	0,969		
			dx	83	81	26,5	26,2	162	2,4	2,4	0,694	0,489		
	width of the middle of the diaphysis	T9	sin	86	75	20,6	19,8	159	1,9	2,1	2,533	0,012	*	rec
			dx	83	82	20,9	19,9	163	2,3	2,2	2,880	0,005	**	rec
	sagittal diameter in the upper foramen nutricium	T8a	sin	86	93	30,0	29,8	177	2,5	2,4	0,520	0,603		
			dx	83	98	29,9	29,6	179	2,4	2,6	0,652	0,515		
	width of the diaphysis in the upper for.nutric.	T9a	sin	86	94	22,2	21,0	178	2,0	2,2	3,750	0,000	***	rec
			dx	83	99	22,3	21,3	180	2,2	1,9	3,458	0,001	**	rec
	circumference of the middle of the diaphysis	T10	sin	86	66	72,4	71,7	150	5,2	4,6	0,819	0,414		
			dx	84	64	72,3	72,0	146	5,8	4,9	0,288	0,774		
	circumference of the diaphysis on the for.nutric.	T10a	sin	86	80	81,2	80,5	164	5,9	5,8	0,820	0,413		
			dx	84	74	81,1	80,2	156	5,8	6,1	0,920	0,359		
	minimum circumference of the diaphysis	T10b	sin	86	75	65,6	66,0	159	4,5	3,9	-0,575	0,566		
			dx	85	67	65,7	66,2	150	4,8	3,7	-0,739	0,461		

Table 3. Studied DA. Results of paired t-tests of males from the recent population.

Expanatory notes: diameters specified in mm; t-value - value of the t-test; df – degrees of freedom; N – number of dimensions; Std.Dev. – standard deviation; p – test level attained; significance levels: * = 5%, ** = 1%, *** = 0.1%

	Measurements	Abbr.	N	Mean $_{sin}$	Std.Dv.	Mean $_{dx}$	Std. Dv.	t-test	p	Signf.	Larger
SCAPULA	anatomical width	Sc1	80	161,9	9,1	161,3	8,6	1,334	0,186		
	anatomical length	Sc2	112	104,6	6,3	104,0	5,8	3,104	0,002	**	sin
	length of the margo lateralis	Sc3	112	138,3	8,1	138,0	8,5	1,000	0,319		
CLAVICLE	maximum clavicle length	Cl1	97	150,8	8,0	149,2	7,8	3,334	0,001	**	sin
	vertical diameter	Cl4	112	11,1	1,3	11,3	1,5	-1,815	0,072		
	sagittal diameter	Cl5	112	12,6	1,4	13,0	1,4	-3,040	0,003	**	dx
HUMERUS	maximum length of the humerus	H1	117	322,4	17,3	325,7	16,7	-9,933	0,000	***	dx
	width of the upper epiphysis	H3	118	50,5	2,3	51,4	2,3	-8,274	0,000	***	dx
	width of the lower epiphysis	H4	118	61,7	3,8	62,2	3,9	-3,544	0,001	***	dx
	maximum diameter of the middle of the diaphysis	H5	120	23,2	1,9	23,8	2,1	-5,344	0,000	***	dx
	minimum diameter of the middle of the diaphysis	H6	120	18,6	1,7	18,9	1,7	-4,698	0,000	***	dx
	maximum transverse diameter of the head	H9	112	44,3	2,0	44,7	2,3	-3,145	0,002	**	dx
	maximum vertical diameter of the head	H10	118	48,0	2,4	48,5	2,2	-4,148	0,000	***	dx
ULNA	maximum length of the ulna	U1	100	255,4	13,2	257,5	13,1	-6,387	0,000	***	dx
	sagittal diameter of the diaphysis	U11	103	14,3	1,3	14,4	1,4	-0,904	0,368		
	width of the diaphysis	U12	103	17,5	1,4	17,7	1,5	-1,618	0,109		
RADIUS	maximum length of the radius	R1	96	237,0	11,9	239,7	12,0	-8,445	0,000	***	dx
	maximum width of the diaphysis	R4	97	17,8	1,6	18,2	1,7	-3,523	0,001	***	dx
	sagittal diameter of the diaphysis	R5	97	12,4	1,1	12,5	1,1	-1,026	0,308		
	width of the middle of the diaphysis	R4a	98	16,7	1,6	17,3	1,6	-4,570	0,000	***	dx
	sagittal diameter of the middle of the diaphysis	R5a	98	12,7	1,1	12,8	1,0	-1,440	0,153		
FEMUR	maximum length of the femur	F1	66	451,8	23,5	450,9	22,8	1,457	0,150		
	physiological length	F2	66	449,7	23,2	448,0	22,6	2,761	0,007	**	sin
	sagittal diameter of the middle of the diaphysis	F6a	67	28,5	2,4	28,7	2,5	-1,130	0,262		
	transverse diameter of the middle of the diaphysis	F7a	67	28,6	2,4	28,5	2,3	0,639	0,525		
	upper transverse diameter of the diaphysis	F7b	67	30,8	2,7	30,6	2,7	1,390	0,169		
	upper sagittal diameter of the diaphysis	F7c	67	28,7	2,2	28,0	2,3	5,457	0,000	***	sin

	Measurements	Abbr.	N	Mean $_{sin}$	Std.Dv.	Mean $_{dx}$	Std. Dv.	t-test	p	Signf.	Larger
FEMUR	lower transverse diameter of the diaphysis	F7d	67	35,9	4,0	35,7	4,1	0,878	0,383		
	lower sagittal diameter of the diaphysis	F7e	67	31,7	3,1	31,1	2,9	4,243	0,000	***	sin
	subtrochanteric transverse diameter of the diaph.	F9	67	33,7	2,6	33,7	2,6	-0,168	0,867		
	subtrochanteric sagittal diameter of the diaphysis	F10	67	28,9	2,2	28,5	2,2	2,690	0,009	**	sin
	circumference of the middle of the diaphysis	F8	67	87,3	5,7	87,2	5,7	0,521	0,604		
	upper widht of the epiphysis	F13	66	101,8	6,3	102,0	5,9	-0,327	0,745		
	epicondylar width	F21	67	82,1	4,5	82,8	4,5	-3,339	0,001	**	dx
	vertical diameter of the head	F18	66	48,6	2,6	48,8	2,7	-0,976	0,333		
	transverse diameter of the head	F19	66	48,3	2,4	48,4	2,7	-0,757	0,452		
FIBULA	maximum length of the fibula	Fi1	93	359,2	24,6	359,3	23,8	-0,170	0,865		
TIBIA	overal length tibie	T1	47	367,2	21,4	367,7	20,8	-0,622	0,537		
	medial length	T1b	46	356,8	20,3	357,5	20,5	-0,811	0,422		
	maximum width of the upper epiphysis	T3	46	74,6	2,9	74,2	3,0	2,008	0,051		
	width of the lower epiphysis	T6	47	48,5	3,0	48,1	2,9	1,449	0,154		
	minimum diameter of the middle of the diaphysis	T8	53	29,4	2,7	29,5	2,3	-0,855	0,396		
	width of the middle of the diaphysis	T9	53	22,7	2,0	22,6	2,1	0,484	0,630		
	sagittal diameter in the upper foramen nutricium	T8a	51	33,8	3,3	33,7	3,0	0,409	0,684		
	width of the diaphysis in the upper for.nutric.	T9a	51	25,0	2,1	25,1	2,4	-0,461	0,647		
	circumference of the middle of the diaphysis	T10	53	80,4	5,9	79,8	5,6	1,965	0,055		
	circumference of the diaphysis on the for.nutric.	T10a	51	91,2	7,3	91,0	6,8	0,446	0,657		
	minimum circumference of the diaphysis	T10b	53	71,8	5,1	71,7	4,9	0,778	0,440		

Table 4. Studied DA. Results of paired t-tests of females from the recent population (for legend see Table 3).

	Measurements	Abbr.	N	Mean $_{sin}$	Std.Dv.	Mean $_{dx}$	Std. Dv.	t-test	p	Signf.	Larger
SCAPULA	anatomical width	Sc1	78	144,3	9,0	144,4	8,9	-0,076	0,939		
	anatomical length	Sc2	112	96,6	5,5	96,7	5,6	-0,343	0,733		
	length of the margo lateralis	Sc3	106	125,2	8,9	126,3	8,8	-4,003	0,000	***	dx
CLAVICLE	maximum clavicle length	Cl1	75	136,1	7,1	134,4	7,1	4,548	0,000	***	sin
	vertical diameter	Cl4	108	9,1	1,3	9,2	1,2	-0,465	0,643		
	sagittal diameter	Cl5	108	10,9	1,2	11,4	1,3	-4,696	0,000	***	dx
HUMERUS	maximum length of the humerus	H1	125	297,7	15,2	301,2	15,2	-10,003	0,000	***	dx
	width of the upper epiphysis	H3	125	44,8	2,5	45,5	2,6	-7,016	0,000	***	dx
	width of the lower epiphysis	H4	126	54,0	3,2	54,8	3,3	-5,608	0,000	***	dx
	maximum diameter of the middle of the diaph.	H5	127	20,6	1,6	21,2	1,6	-6,655	0,000	***	dx
	minimum diameter of the middle of the diaph.	H6	127	16,2	1,4	16,4	1,5	-3,675	0,000	***	dx
	maximum transverse diameter of the head	H9	112	39,0	2,0	39,5	2,2	-4,578	0,000	***	dx
	maximum vertical diameter of the head	H10	119	42,1	2,2	42,5	2,5	-3,214	0,002	**	dx
ULNA	maximum length of the ulna	U1	118	230,8	11,6	234,0	12,2	-10,806	0,000	***	dx
	sagittal diameter of the diaphysis	U11	126	11,9	1,1	12,2	1,1	-4,024	0,000	***	dx
	width of the diaphysis	U12	126	15,0	1,2	15,3	1,3	-4,887	0,000	***	dx
RADIUS	maximum length of the radius	R1	123	212,8	11,7	216,3	12,2	-9,617	0,000	***	dx
	maximum width of the diaphysis	R4	128	15,6	1,6	15,9	1,5	-4,078	0,000	***	dx
	sagittal diameter of the diaphysis	R5	128	10,6	0,8	10,6	0,8	-0,961	0,338		
	width of the middle of the diaphysis	R4a	128	14,7	1,4	15,1	1,4	-6,121	0,000	***	dx
	sagittal diameter of the middle of the diaphysis	R5a	128	10,6	0,8	10,7	0,8	-2,350	0,020	*	dx
FEMUR	maximum length of the femur	F1	58	415,0	19,2	414,6	19,6	0,681	0,499		
	physiological length	F2	58	411,6	19,3	410,5	19,8	2,106	0,040	*	sin
	sagittal diameter of the middle of the diaphysis	F6a	64	25,9	2,0	25,9	2,2	-0,244	0,808		
	transverse diameter of the middle of the diaphysis	F7a	64	26,8	2,5	26,5	2,2	2,116	0,038	*	sin
	upper transverse diameter of the diaphysis	F7b	64	29,3	2,6	28,6	2,8	3,550	0,001	***	sin
	upper sagittal diameter of the diaphysis	F7c	64	25,7	2,3	25,2	2,1	2,657	0,010	**	sin

	Measurements	Abbr.	N	Mean $_{sin}$	Std.Dv.	Mean $_{dx}$	Std. Dv.	t-test	p	Signf.	Larger
	lower transverse diameter of the diaphysis	F7d	64	33,0	3,7	33,0	3,8	0,000	1,000		
	lower sagittal diameter of the diaphysis	F7e	64	28,7	2,2	28,0	2,4	3,832	0,000	***	sin
	subtrochanteric transverse diameter of the diaph.	F9	63	31,5	2,3	31,2	2,5	1,474	0,146		
	subtrochanteric sagittal diameter of the diaphysis	F10	63	25,9	1,9	25,9	2,2	0,000	1,000		
FEMUR	circumference of the middle of the diaphysis	F8	65	80,2	5,9	79,6	5,6	2,100	0,040	*	sin
	upper width of the epiphysis	F13	59	88,1	5,6	88,6	5,8	-2,151	0,036	*	dx
	epicondylar width	F21	59	73,8	3,9	73,9	3,8	-0,769	0,445		
	vertical diameter of the head	F18	58	43,1	2,8	43,1	2,9	-0,136	0,892		
	transverse diameter of the head	F19	58	42,5	2,2	42,7	2,3	-1,763	0,083		
FIBULA	maximum length of the fibula	Fi1	81	328,6	16,4	328,3	16,6	0,762	0,449		
	overal length tibie	T1	63	338,5	17,5	337,9	17,2	1,257	0,214		
	medial length	T1b	59	329,4	17,6	328,9	17,4	1,137	0,260		
	maximum width of the upper epiphysis	T3	55	66,7	3,4	66,6	3,7	0,457	0,649		
	width of the lower epiphysis	T6	54	44,0	2,6	44,1	2,7	-0,339	0,736		
	minimum diameter of the middle of the diaphysis	T8	69	26,6	2,4	26,7	2,5	-0,173	0,863		
TIBIA	width of the middle of the diaphysis	T9	69	20,6	1,9	20,8	2,3	-1,396	0,167		
	sagittal diameter in the upper foramen nutricium	T8a	69	29,9	2,6	29,9	2,5	0,346	0,730		
	width of the diaphysis in the upper for.nutric.	T9a	69	22,2	2,0	22,3	2,3	-0,956	0,343		
	circumference of the middle of the diaphysis	T10	70	72,1	4,9	72,1	6,0	-0,082	0,935		
	circumference of the diaphysis on the for.nutric.	T10a	70	80,8	5,4	80,9	6,1	-0,271	0,788		
	minimum circumference of the diaphysis	T10b	71	65,5	4,4	65,6	4,8	-0,518	0,606		

Table 5. Studied DA. Results of paired t-tests of males from the Great Moravian population (for legend see Table 3).

	Measurements	Abbr.	N	Mean $_{sin}$	Std.Dv.	Mean $_{dx}$	Std. Dv.	t-test	p	Signf.	Larger
CLAVICLE	maximum clavicle length	Cl1	8	151,8	13,0	149,9	13,7	0,535	0,609		
	vertical diameter	Cl4	39	11,1	1,4	11,5	1,5	-1,833	0,075		
	sagittal diameter	Cl5	39	12,7	1,2	12,9	1,5	-1,062	0,295		
HUMERUS	maximum length of the humerus	H1	24	328,3	17,2	333,6	16,1	-6,226	0,000	***	dx
	width of the upper epiphysis	H3	11	49,4	2,6	50,5	2,8	-3,357	0,007	**	dx
	width of the lower epiphysis	H4	20	62,8	4,2	63,9	3,7	-3,399	0,003	**	dx
	maximum diameter of the middle of the diaphysis	H5	58	22,8	1,7	23,8	1,9	-7,856	0,000	***	dx
	minimum diameter of the middle of the diaphysis	H6	60	18,5	1,5	18,9	1,6	-2,572	0,013	*	dx
	maximum transverse diameter of the head	H9	3	42,3	2,5	44,0	2,6	-2,500	0,130		
	maximum vertical diameter of the head	H10	10	45,9	7,4	47,1	8,1	-3,343	0,009	**	dx
ULNA	maximum length of the ulna	U1	12	273,8	14,4	275,1	14,3	-1,470	0,170		
	sagittal diameter of the diaphysis	U11	37	14,4	1,7	14,9	1,5	-3,074	0,004	**	dx
	width of the diaphysis	U12	36	17,7	2,0	17,6	1,7	0,373	0,711		
RADIUS	maximum length of the radius	R1	13	245,0	20,2	246,2	19,7	-2,259	0,043	*	dx
	maximum width of the diaphysis	R4	26	17,5	1,5	18,2	1,2	-3,241	0,003	**	dx
	sagittal diameter of the diaphysis	R5	27	12,3	1,2	12,5	1,2	-1,412	0,170		
	width of the middle of the diaphysis	R4a	27	16,5	1,6	16,9	1,5	-2,294	0,030	*	dx
	sagittal diameter of the middle of the diaphysis	R5a	26	12,2	0,8	12,4	0,8	-1,413	0,170		
FEMUR	maximum length of the femur	F1	28	451,5	26,8	449,7	27,3	2,120	0,043	*	
	physiological length	F2	42	450,8	26,1	449,4	26,3	2,117	0,040	*	
	sagittal diameter of the middle of the diaphysis	F6a	67	28,8	2,6	28,7	2,8	0,394	0,695		
	transverse diameter of the middle of the diaphysis	F7a	65	29,0	2,5	28,1	2,3	7,913	0,000	***	
	upper transverse diameter of the diaphysis	F7b	60	32,3	2,4	31,0	3,0	4,347	0,000	***	
	upper sagittal diameter of the diaphysis	F7c	62	27,4	2,5	27,1	2,8	2,537	0,014	*	
	lower transverse diameter of the diaphysis	F7d	53	35,5	4,1	34,9	3,9	3,951	0,000	***	sin
	lower sagittal diameter of the diaphysis	F7e	53	31,0	2,6	30,9	2,5	0,513	0,610		
	subtrochanteric transverse diameter of the diaph.	F9	69	34,7	2,6	33,8	2,5	4,626	0,000	***	sin
	subtrochanteric sagittal diameter of the diaphysis	F10	69	27,9	2,5	27,7	2,1	1,656	0,102		

	Measurements	Abbr.	N	Mean $_{sin}$	Std.Dv.	Mean $_{dx}$	Std. Dv.	t-test	p	Signf.	Larger
FEMUR	circumference of the middle of the diaphysis	F8	55	89,7	5,8	89,0	5,7	2,390	0,020	*	sin
	upper widht of the epiphysis	F13	35	100,5	7,8	100,6	7,7	-0,193	0,848		
	epicondylar width	F21	14	81,9	5,3	81,9	5,2	-0,234	0,818		
	vertical diameter of the head	F18	33	48,6	2,3	48,6	2,4	0,000	1,000		
	transverse diameter of the head	F19	24	48,0	2,3	48,4	2,9	-1,895	0,071		
TIBIA	overal length tibie	T1	25	378,3	25,2	376,4	24,8	3,201	0,004	**	sin
	medial length	T1b	17	375,2	26,3	373,6	26,0	1,765	0,097		
	maximum width of the upper epiphysis	T3	4	77,0	0,8	74,8	1,5	2,029	0,135		
	width of the lower epiphysis	T6	12	47,9	4,2	47,8	4,2	0,432	0,674		
	minimum diameter of the middle of the diaphysis	T8	49	29,1	2,6	29,3	2,3	-1,070	0,290		
	width of the middle of the diaphysis	T9	50	22,2	2,1	22,2	2,0	-0,330	0,743		
	sagittal diameter in the upper foramen nutricium	T8a	58	33,3	3,3	33,3	2,9	-0,275	0,784		
	width of the diaphysis in the upper for.nutric.	T9a	59	23,9	2,4	23,9	2,2	-0,219	0,827		
	circumference of the middle of the diaphysis	T10	47	79,9	5,3	79,6	5,2	0,975	0,335		
	circumference of the diaphysis on the for.nutric.	T10a	56	90,3	6,6	89,5	6,2	2,064	0,044	*	sin
	minimum circumference of the diaphysis	T10b	54	72,8	5,6	72,5	4,5	0,664	0,510		

Table 6. Studied DA. Results of paired t-tests of females from the Great Moravian population (for legend see Table 3).

	Measurements	Abbr.	N	Mean $_{sin}$	Std.Dv.	Mean $_{dx}$	Std. Dv.	t-test	p	Signf.	Larger
CLAVICLE	maximum clavicle length	Cl1	17	132,2	8,9	131,0	8,6	1,605	0,128		
	vertical diameter	Cl4	39	9,6	0,9	9,6	1,1	0,198	0,844		
	sagittal diameter	Cl5	40	10,6	1,2	10,7	1,1	-0,781	0,440		
HUMERUS	maximum length of the humerus	H1	30	290,6	15,8	293,6	15,1	-4,280	0,000	***	dx
	width of the upper epiphysis	H3	23	43,6	2,5	44,2	2,8	-1,845	0,079		
	width of the lower epiphysis	H4	23	54,5	2,8	55,2	3,0	-2,626	0,015	*	dx
	maximum diameter of the middle of the diaph.	H5	64	20,1	1,5	20,5	1,5	-3,291	0,002	**	dx
	minimum diameter of the middle of the diaph.	H6	66	15,5	1,3	15,8	1,4	-1,626	0,109		
	maximum transverse diameter of the head	H9	10	38,6	2,0	39,4	1,3	-2,228	0,053		
	maximum vertical diameter of the head	H10	20	41,5	2,4	41,3	2,4	1,045	0,309		
ULNA	maximum length of the ulna	U1	15	239,8	7,7	242,3	8,4	-3,510	0,003	**	dx
	sagittal diameter of the diaphysis	U11	42	11,6	1,3	12,1	1,5	-3,490	0,001	**	dx
	width of the diaphysis	U12	42	14,5	1,6	14,9	1,6	-2,638	0,012	*	dx
RADIUS	maximum length of the radius	R1	17	214,6	13,6	217,8	13,9	-6,246	0,000	***	dx
	maximum width of the diaphysis	R4	33	15,1	1,2	15,4	1,4	-2,101	0,044		
	sagittal diameter of the diaphysis	R5	36	10,6	1,1	10,9	1,2	-2,142	0,039	*	dx
	width of the middle of the diaphysis	R4a	35	14,0	1,3	14,3	1,6	-1,819	0,078		
	sagittal diameter of the middle of the diaphysis	R5a	33	10,5	0,8	10,4	0,9	0,571	0,572		
FEMUR	maximum length of the femur	F1	47	410,3	17,6	409,4	18,0	1,872	0,068		
	physiological length	F2	57	406,4	14,5	405,0	14,7	2,909	0,005	**	sin
	sagittal diameter of the middle of the diaphysis	F6a	96	24,5	2,4	24,3	2,3	1,520	0,132		
	transverse diameter of the middle of the diaphysis	F7a	95	25,7	2,0	25,3	2,0	3,956	0,000	***	sin
	upper transverse diameter of the diaphysis	F7b	78	29,2	2,4	28,9	2,6	1,828	0,071		
	upper sagittal diameter of the diaphysis	F7c	76	23,4	2,4	23,3	2,6	0,681	0,498		
	lower transverse diameter of the diaphysis	F7d	74	31,4	3,6	30,9	3,4	3,158	0,002	**	sin
	lower sagittal diameter of the diaphysis	F7e	73	26,5	2,5	26,2	2,3	2,021	0,047	*	sin
	subtrochanteric transverse diameter of the diaph.	F9	89	31,0	2,4	30,9	2,5	0,600	0,550		

	Measurements	Abbr.	N	Mean $_{sin}$	Std.Dv.	Mean $_{dx}$	Std. Dv.	t-test	p	Signf.	Larger
FEMUR	subtrochanteric sagittal diameter of the diaphysis	F10	89	23,9	2,3	23,9	2,5	-0,478	0,634		
	circumference of the middle of the diaphysis	F8	70	79,1	5,4	78,7	5,4	2,159	0,034	*	sin
	upper widht of the epiphysis	F13	45	88,5	5,4	88,6	6,1	-0,380	0,705		
	epicondylar width	F21	21	71,9	2,8	72,0	3,4	-0,149	0,883		
	vertical diameter of the head	F18	40	42,4	2,2	42,5	2,2	-0,552	0,584		
	transverse diameter of the head	F19	34	41,7	2,1	41,9	2,1	-1,643	0,110		
TIBIA	overal length tibie	T1	31	336,7	15,1	335,4	15,5	2,599	0,014	*	sin
	medial length	T1b	23	329,7	15,7	328,0	15,7	3,169	0,004	**	sin
	maximum width of the upper epiphysis	T3	7	65,6	1,7	66,1	2,4	-0,934	0,386		
	width of the lower epiphysis	T6	18	42,0	2,5	41,9	2,3	0,270	0,790		
	minimum diameter of the middle of the diaphysis	T8	56	26,6	2,1	26,6	2,1	0,000	1,000		
	width of the middle of the diaphysis	T9	57	19,9	2,1	20,1	2,0	-0,714	0,478		
	sagittal diameter in the upper foramen nutricium	T8a	66	30,2	2,3	30,0	2,4	0,745	0,459		
	width of the diaphysis in the upper for.nutric.	T9a	69	21,3	2,2	21,4	1,9	-0,860	0,393		
	circumference of the middle of the diaphysis	T10	56	71,6	4,7	71,9	5,0	-1,166	0,249		
	circumference of the diaphysis on the for.nutric.	T10a	70	80,2	5,6	80,2	6,2	-0,276	0,784		
	minimum circumference of the diaphysis	T10b	63	66,1	3,9	66,1	3,7	-0,278	0,782		

Table 7. Results of evaluation of the FA from the recent population (FA1, FA2, FA4, FA6: indices of the calculation of FA values. FA1: mean /R-L/; FA2: mean {/R-L/ / [(R+L) /2]}; FA4: var (R-L); FA6: var {(R-L) / [(R+L) /2]}; DA – dimension for which DA presence was found; for the nomenclature of measures see Table 3).

Males				
Abbr. of Measur.	FA1	FA2	FA4	FA6
Sc1	2,925	0,018	13,423	0,001
Sc3	2,304	0,017	8,917	0,000
Cl4	0,821	0,073	1,301	0,010
U12	0,602	0,034	0,719	0,002
F1	3,500	0,008	22,845	0,000
F6a	0,985	0,034	2,255	0,003
F7a	0,970	0,034	1,765	0,002
F8	1,567	0,018	4,385	0,001
F13	2,364	0,023	8,955	0,001
F19	0,864	0,018	1,277	0,001
Fi1	2,559	0,007	13,243	0,000
T1	3,574	0,010	30,973	0,000
T1b	3,957	0,011	37,410	0,000
T3	1,217	0,016	2,554	0,000
T6	1,167	0,024	2,608	0,001
T8	1,132	0,040	2,530	0,003
T9	1,000	0,044	1,972	0,004
T8a	1,235	0,037	2,873	0,003
T9a	0,863	0,034	1,445	0,002
T10	1,358	0,017	3,759	0,001
T10a	2,157	0,024	9,648	0,001
T10b	1,170	0,016	3,059	0,001

Table 8. Results of evaluation of the FA from the medieval population (for legend see Table 7).

Males				
Abbr. of Measur.	FA1	FA2	FA4	FA6
Cl1	6,875	0,046	85,859	0,004
Cl4	0,949	0,084	1,673	0,012
U1	2,500	0,009	9,056	0,000
F6a	0,866	0,030	1,519	0,002
F13	1,200	0,012	2,968	0,000
F19	0,458	0,012	0,901	0,000
T1b	2,941	0,008	12,014	0,000
T6	0,417	0,009	0,410	0,000
T8	0,878	0,031	1,415	0,002
T9	0,560	0,025	0,718	0,001
T8a	1,483	0,045	3,581	0,003
T9a	0,847	0,035	1,389	0,002
T10	1,617	0,020	4,294	0,001
T10b	1,259	0,018	2,497	0,000
Females				
Abbr. of Measur.	FA1	FA2	FA4	FA6
Cl1	2,529	0,019	9,474	0,001
Cl4	0,590	0,061	0,640	0,007
H3	1,261	0,029	2,749	0,001
H9	1,200	0,031	1,160	0,001
H10	0,750	0,018	1,088	0,001
R4a	0,714	0,051	1,016	0,006

Females				
Abbr. of Measur.	FA1	FA2	FA4	FA6
Sc1	2,981	0,015	19,230	0,001
Sc2	1,723	0,018	6,110	0,001
Cl4	0,713	0,078	1,063	0,013
F1	3,517	0,008	21,070	0,000
F6a	0,813	0,031	1,030	0,002
F19	0,397	0,009	0,441	0,000
Fi1	2,296	0,007	8,408	0,000
T1	2,794	0,008	12,816	0,000
T1b	2,966	0,009	13,420	0,000
T3	1,364	0,020	4,184	0,001
T6	0,796	0,018	1,423	0,001
T8	0,928	0,035	1,912	0,003
T9	0,765	0,035	1,458	0,003
T8a	0,957	0,032	1,910	0,002
T9a	0,629	0,028	1,001	0,002
T10	1,543	0,020	8,342	0,001
T10a	1,300	0,016	4,809	0,001
T10b	1,099	0,016	3,311	0,001

Males				
Abbr. of Measur.	FA1	FA2	FA4	FA6
F1	3,021	0,007	12,574	0,000
F6a	0,667	0,027	0,875	0,001
F13	1,556	0,017	5,404	0,001
F19	0,412	0,015	0,381	0,000
T6	0,611	0,014	0,719	0,000
T8	0,600	0,022	0,927	0,001
T9	0,772	0,039	1,217	0,003
T8a	1,076	0,036	2,178	0,002
T9a	0,826	0,039	1,563	0,003
T10	1,536	0,021	4,182	0,001
T10a	1,886	0,024	6,678	0,001
T10b	0,937	0,014	1,823	0,000

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Anthropological and epidemiological characterization of Great-Moravian population in connection with the social and economic structure

Harris Lines in the Non-adult Great Moravian Population from Mikulčice – the Comparison of Inhabitants of the Castle and Sub-castle Area

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Harris lines (HL) have been recognised as indicators of health status since the 1930s (Harris 1931). Although a number of research projects have studied the causes of HL development, their aetiology remains unclear. In general, these transversal, sclerotised layers are considered to be a reaction to a pathological condition or some form of malnutrition. We evaluated HL in a group of 122 non-adult individuals from the Great Moravian power centre at Mikulčice. We monitored the incidence of these lines on the long bones of limbs- the humerus, femur and tibia. This study confirmed that the highest incidence of HL was on the distal section of the tibia. The lines most frequently formed in the period between the 1st and 3rd year of life. A relationship between the number of lines and social status of the given individual (localisation of the grave within the agglomeration, the character of the grave equipment) was not demonstrated.

Key words: Harris lines – Great Moravian population – non-adults – non-specific stress

1. Introduction

Harris lines (HL) are transversal, sclerotised lyers within spongious bone tissue. They were first described by H.A. Harris who studied their incidence in the recent population and are thus named in his honour (Harris 1931). They develop in the region of the metaphysis of long bones and run perpendicular to the bone diaphysis, parallel to the epiphysis (Hummert/Van Greven 1985). They either cross it partially or completely. Apart from long bones, they may also occur on flat bones, such as for example the scapula, near the *fossa articularis,* and the pelvis, near the *crista iliaca*. They have also been observed on short bones, on the carpal and tarsal bones, where they develop around the bone centres (Kühl 1980).

HL may be evaluated on longitudinal bone sections or on X-Ray images. The use of X-Rays, a non-invasive method, is preferred.

HL are a manifestation of a temporary or complete growth arrest during bone development and they develop as a result of discordance of the growth mechanism between cartilage cells and osteoblasts (Vyhnánek et al. 1986). Subsequent resumption of growth is necessary for the development of HL (Steinbock 1976).

HL manifest with various intensity. It is presumed that the intensity of HL manifestation reflects the severity of the stress suffered and its duration. Thus, intensity, or more exactly the density of the lines, is taken into consideration during their evaluation. Sometimes, though, these lines may show some variability in intensity in one or more of their regions (throughout their

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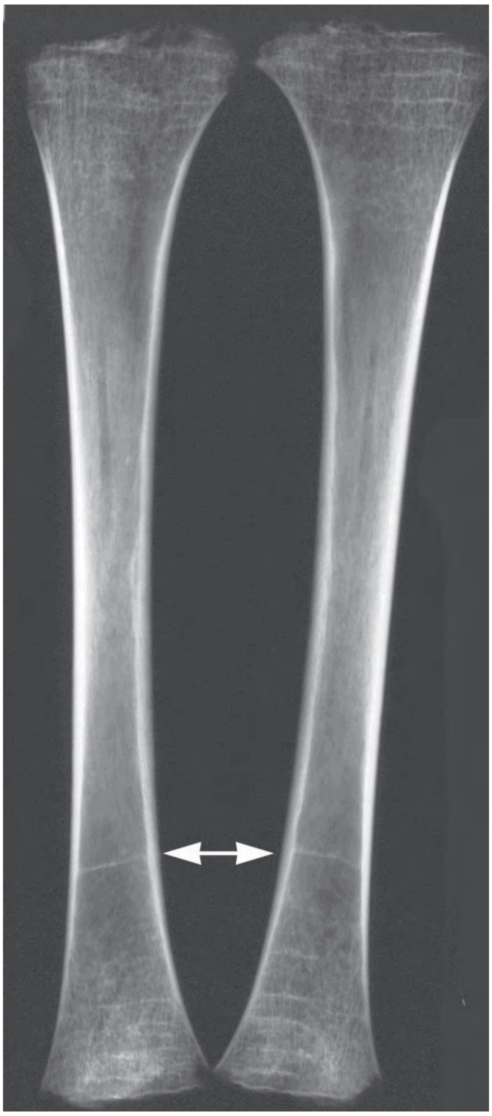
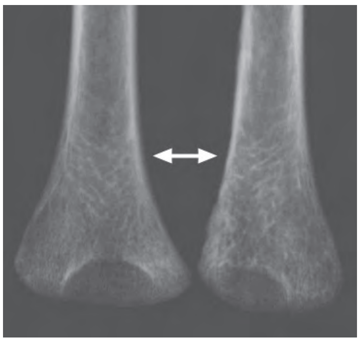


Figure 1. Harris lines on an X-Ray image of the tibia.

2a



2b

Figure 2a, 2b. Harris lines on an X-Ray image of the proximal femur (a) and the distal humerus (b).

course). As a rule, they are less intense near the marrow cavity (Huges/Heylings/Power 1996).

The tibia is the most suitable bone for studying HL. HL occur more frequently in the distal sections of the tibia than in other bones. Also, thanks to the shape of the tibia, examination and analysis of these lines is easier, compared to the other long bones. Problematic areas are especially those with multiple epiphyses and apophyses, for example the proximal section of the femur or the distal part of the humerus. Here, the course of the lines may be tortuous and of varying intensity, which may complicate their analysis.

Although research of HL has been underway since the 1930s, their aetiology remains unclear. Many factors play a role in the development of HL (Vyhnánek/Stloukal 1991). Various forms of malnutrition, especially vitamin or protein deficiency, are quoted as the most frequent cause of their development (Wolbach 1947; Park/Richter 1953; Dreizen/Spirakis/Stone 1964). Other presumed causes may include acute diseases, especially childhood infectious diseases – measles, mumps (Marshall 1968; Gindhart 1969), various type of anaemia or heavy metal poisoning (Caffey 1931; Wells 1967). Some authors also see a connection between the development of HL and psychological stress (Sonntag/Comstock 1938). This, though, is probably an attendant symptom of physical stress and exertion. As HL also develop in the prenatal and perinatal period, and diseases of the mother or her malnutrition may play a role in their development (Harris 1931; Sonntag/Comstock 1938). Development of these lines may also be due to neonatal shock at delivery (Wells 1964, 1967) or to the so-called "weaning hypothesis", i.e. the change in quality of nutrition when switching from breastfeeding to a normal diet (see enamel hypoplasia) (Lewis/Roberts 1997).

Most studies focusing on the aetiology of HL were conducted on animals, where it is relatively easy to set and regulate the experimental conditions (Park/Richter 1953; Stewart/Plat 1957). This type of experiments mainly focuses on the monitoring of nutritional deficiencies or of various forms of poisoning that either induce the development of HL or not. From an anthropological point of view, longitudinal studies conducted on living individuals of the current population are the most interesting sources of information regarding HL. Their contribution lies in the possibility of monitoring the gradual development and subsequent resorption of these lines in real time. Findings from such studies may then be applied to historical material (e.g. Wells 1967). Unfortunately, today, such types of studies are no longer possible due to ethical and medical reasons.

A more or less solitary study of this type is the work of Patricia Gindhart from 1969. This is a longitudinal study involving more than 650 boys and girls, including medical records of diseases suffered and X-Ray images at relatively frequent intervals (every three moths up to the age of one, then every six months up to the age of 12 and annually from the age of 12 to 14). Among others, this study showed that HL occur after suffering an illness in only 25% of cases. Thus, it was previously erroneously presumed that HL reflect all more serious diseases suffered.

Nonetheless, thanks to the presumed correlation between the number of HL and the health status of a population, it is possible to infer from their various incidence the different living conditions both among populations and among individuals within a single population. Most of the current studies involving past populations are based on this fact. They thus restrict themselves only to the monitoring of the number of HL, as any detailed study of the causes of HL development is not possible.

In the case of HL, we may also estimate the period of their formation. This is based on the understanding of the growth of long bones and on the position of the line within the bone (Hunt/Hatch 1983; Byers 1991). Thus, it is possible to estimate the approximate age when the given individual experienced a certain stressful event.

The study of HL is naturally limited by several facts. As a consequence of the re-modelling of the internal bone structure in later life and the associated resorption, the application of HL in the adult population is restricted. Just like the development of HL, bone re-modelling is individual. Sometimes, it is possible to observe a greater number of lines even in individuals of advanced age. The non-adult population is preferred, though, for the study of HL lines. Yet bias and distortion may occur even in such cases, as individuals who died at a young age may represent unusually weak and ill individuals.

Despite all these drawbacks, Harris lines, along with many other signs, remain one of the indicators of the health status of individuals from past populations.

2. Materials

The skeletal material comes from the Great Moravian power centre at Mikulčice, which dates to the 9th-10th century AD (Poláček 2000). Several burial sites have been uncovered at this locality, usually in the vicinity of churches, both within the area of the castle and the sub-castle.

In our study, we used the skeletal remains of 73 individuals buried near the churches in the area of the castle itself– acropolis (Ist - Vth church, XIIth church) and 49 individuals from several burial sites located in the sub-castle area (VIth, IXth church, Klášteřisko and Kostelisko). This selection, along with the differentiation of individuals according to their grave equipment, enables the monitoring and comparison of the health status of individuals on the basis of their presumed social status, and thus their living conditions.

The skeletal material used for the study of Harris lines included 122 non-adult individuals of undetermined sex. The evaluation was conducted only in those individuals who had at least two long bones preserved – femur, tibia or humerus. We evaluated a total of 106 non-adult individuals with minimally one femur, 75 individuals with minimally one tibia and 94 individuals with minimally one humerus. For evaluation of side asymmetry associated with HL incidence,

Table 1. List of burial grounds studied.

Site	Burial-ground	Castle/Sub-castke	Publication	N of graves
I., II. church	I.	castle	Stloukal 1963	19
III. church (bazilica)	II.	castle	Stloukal 1967	45
IV. church	III.	castle	Stloukal 1969	5
V. church	V.	castle		1
XII. church		castle	Stloukal/Vyhnánek 1998	3
VI. church	IV.	sub-castle	Stloukal 1964	23
IX. church		sub-castle		4
Kostelisko		sub-castle	Velemínský et al. 2005	5
Klášteřisko		sub-castle	Stloukal/Hanáková 1985	17
Total				122

it was necessary to evaluate pairs of bones. Their numbers are summarised in Table 2.

3. Methods

As mentioned previously, this work was conducted on three types of long bones – the femur, tibia and humerus. Most studies use the long bones of the lower limb, where HL are clearly observed thanks to their more rapid growth (Eliot/Souther/Park 1927; Park 1964). This is especially true of the tibia (Gindhart 1969; Hummert/Van Greven 1985; Buikstra/Uberlaker 1994), where the incidence of HL is greatest and the analysis of lines poses no problems. Rapid growth leads to greater distances between the developed lines, and thus facilitates their analysis (Hunt/Hatch 1981). Despite these findings, we additionally analysed HL on the femur and humerus for the purpose of comparison.

Table 2. Number of individuals studied by individual bones.

	N		
	Individuals	Bones	Pairs
Fe	106	181	75
Ti	75	123	48
Hu	94	155	61

The basic prerequisite for bone selection is their good preservation. In order to be able to use a bone, it is important that its compacta, and subsequently internal architecture, remain intact. In view of the aforementioned facts regarding bone re-modelling in later age and the subsequent resorption of lines, we worked with a non-adult population from birth until the age of 18.

It is known from many previous studies that the incidence of HL is symmetrical on both sides, and thus research is usually conducted only on one bone from a pair. In order to confirm this theory and to increase the reliability of the analysis of these lines, we tried to analyse the lines on both bones of a pair whenever the skeleton's state of preservation allowed (for the number of pairs see Table 2).

The selected bones were then X-rayed using the following parameters: focal length 110 cm, range approx. 50mA, approx. 1.25 mAs, time 0.03 s, approx. 46 kV. Each bone was X-rayed in two positions – antero-posterior and medio-lateral. This increases the precision of HL analysis and also reduces observer error (e.g. Vyhnánek/Stloukal 1988). Another possibility is to study HL on a cross-section of the bone, but this method is highly destructive.

The X-rays were then digitised using the Microtek (ScanMaker 64000XL) scanner and SilverFast 4 software. The analysis of the lines itself and the measurement of their distance from the ends of epiphyses was conducted using the Sigma Scan Image Pro 6.0 software for image analysis.

During the analysis itself, we based our investigation on the work of Goodman and Clark (1981). The lines had to be visible to the naked eye and had to occupy minimally one half of the width of the diaphysis. According to the length of the lines, we then divided them into three groups: lines that intersected the whole length of the diaphysis, lines with a length ¼ - ¾ of diaphysis width and lines that occupied less than ¼. We also differentiated the lines according to their intensity into weak and strong lines, and we used only the distinctive lines in our final evaluation.

Statistical evaluation of HL frequency of incidence was conducted using the STATISTICA 6.0 program and Excel 2003.

For greater measurement reliability, we analysed the lines of each bone three times. In the case of tibias, a fourth measurement was conducted with regard to inter-personal measurement error (intra- and inter-personal error was tested with the aid of the Friedman's ANOVA by ranks).

Another outcome of the study of HL was the estimation of the period of their formation. For our calculations, we used the methodology described in the work of S. Byers (1991), which uses several basic dimensions. It has been created for four types of long bones – humerus, radius, femur and tibia.

For the adult population, we based our analysis on four basic dimensions – the total length of the bone, the distance between the distal metaphysis and the distal end of the bone, the distance between the proximal metaphysis and the proximal end of the bone and the distance of the line from the nearer end of the bone; whereby the first three dimensions aid in the calculation of diaphysis length. The method itself is thus based on the calculations of equations derived from the aforementioned dimensions.

For the non-adult population, we monitored only two basic dimensions– diaphysis length measured from the most proximal end to the most distal (T) and the distance between HL and the end of the diaphysis (proximal - P, distal - D), because the epiphyses are not as yet fully synostozed and thus the complicated identification of the metaphyseal border in order to calculate diaphysis length is not necessary. In view of this simplification, we used Byers equation for correction, in accordance with the work of Velemínský et al. 2005 (Table 3).

The results acquired for both the adult and non-adult population represent the percentual ratio of bone length at the level of the observed HL. These must then be related to the ontogenetic model of long bones, i.e. the "actual" period of HL formation must be derived from this. For the non-adult population, we took as our basis the ontogenetic "tables" of the long bones of limbs drawn up directly for the Great Moravian population (Stloukal/Hanáková 1978). In the adult population, it is more appropriate to use the conversion tables cited in Byers' work. We used the method of regression analysis for the statistical

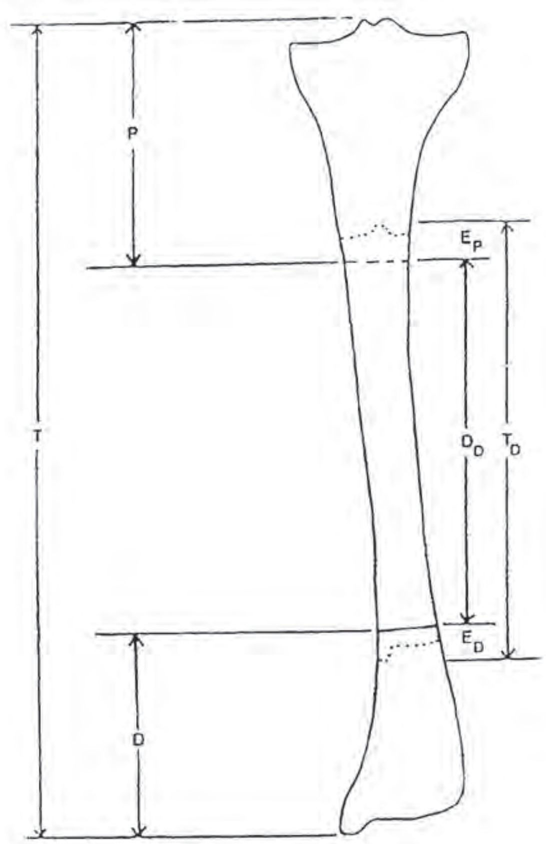


Figure 3. Drawing of bone with areas of measurement for determining age of HL formation (Byers 1991).

Table 3. Modified Byers' method for non-adult populations according to Velemínský et al. 2005.
Explanatory notes: Pct – percent of bone length, T – the total length, P/D – the distance from the transverse line to the closest end (proximal/distal)

		Byers 1991	Velemínský et al. 2005
Fe	prox.	Pct = 1,12 (T - 3,33P) x 100/T	Pct = (T - 3,33P)
	dist.	Pct = 1,12 (T - 1,43D) x 100/T	Pct = (T - 1,43D)
Ti	prox.	Pct = 1,15 (T - 1,75P) x 100/T	Pct = (T - 1,75P)
	dist.	Pct = 1,15 (T - 1,33D) x 100/T	Pct = (T - 1,33D)
Hu	prox.	Pct = 1,09 (T - 1,23P) x 100/T	Pct = (T - 1,23P)
	dist.	Pct = 1,09 (T - 5,26D) x 100/T	Pct = (T - 5,26D)

Table 4. Occurrence of HL on individual long bones of limbs.

		N of ind. with HL									
		N of ind.	N of HL	0		1		2 to 4		More than 5	
				N	%	N	%	N	%	N	%
Fe	prox .	106	11	100	94,3	2	1,9	4	3,8	-	-
	dist.		91	49	46,2	34	32,1	23	21,7	-	-
	total		102	47	44,3	32	30,2	26	24,5	1	0,9
Ti	prox .	75	87	33	44,0	15	20,0	27	36,0	-	-
	dist.		131	11	14,7	20	26,7	43	57,3	1	1,3
	total		218	8	10,7	11	14,7	40	53,3	16	21,3
Hu	prox .	94	4	91	96,8	2	2,1	1	1,1	-	-
	dist.		2	92	97,9	2	2,1	-	-	-	-
	total		6	89	94,7	4	4,3	1	1,1	-	-

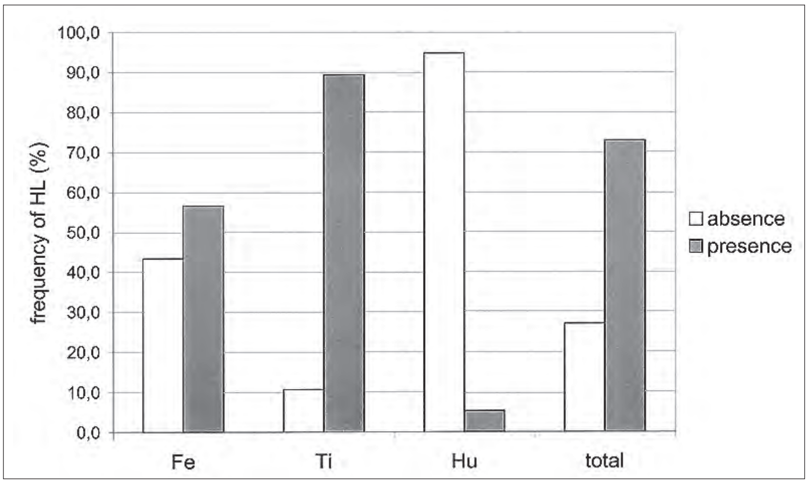
evaluation of the irregular distribution of HL in relation to age.

Based on the known findings regarding HL development, it may be presumed that the incidence of HL will be higher in individuals with worse living conditions. We thus studied the relationship between the living standard of individuals and the number of HL; or rather we compared the incidence of HL among individuals of various social status.

We inferred the social status of individuals from the character of their grave equipment (the archive of the Institute of Archaeology of the Czech Academy of Sciences, Brno). We also took into consideration the position of the given grave within the Mikulčice settlement agglomeration, that is whether the burial site was within the castle grounds themselves (Ist-Vth, and XIIth church) or whether is was within the sub-castle area (VIth and IXth church, Klášteřisko and Kostelisko).

As to grave equipment, in view of the period from which the burial site originates, its exploitation in the determination of social status may be complicated by the onset of Christianisation of the population. At the time, pagan traditions were being abandoned, including the placing of gifts and offerings in the grave.

Nonetheless, we still presumed that individuals with poorer grave equipment or those buried in the sub-castle area or its surroundings probably enjoyed lower living standards, and thus we could expect a higher incidence of HL. On the contrary, we presumed that individuals with richer grave equipment or those buried within the castle itself would have a lower number of HL due to their better living conditions.



Graph 1. Occurrence of HL on individual long bones of limbs.

We divided the individuals according to their grave equipment using two methods. The first was based on the work of V. Unzeitigová from 2000. This divides grave equipment into three groups:

1st group: jewellery, weapons, spurs, etc.
2nd group: objects of daily use (knives, vessels, etc.)
3rd group: no grave equipment

A much simpler division into two groups may be found in the works of Stloukal (1970) and Velemínský (2000):

1st group: graves with swords, spurs, axes; graves with gold, silver or bronze objects.
2nd group: graves without equipment; graves with knives or other minor objects made of iron, ceramic or glass.

We used the χ^2-test to verify our premises regarding both our comparison of the individuals from the castle and sub-castle, and the distribution of HL according to grave equipment.

4. Results

We observed a minimum of one line in more than 70% of individuals (89 from a total of 122 evaluated). No HL were observed in the remaining 33 individuals. The number of individuals with at least one line on individual bones is summarised in Table 4 and Graph 1.

As presumed, the highest incidence of HL was recorded on the tibia (nearly in 90% of cases). Minimally one line was observed on the femur in more than 56% of individuals, while the incidence of HL on the humerus represented only 5% (6 lines in 4 individuals).

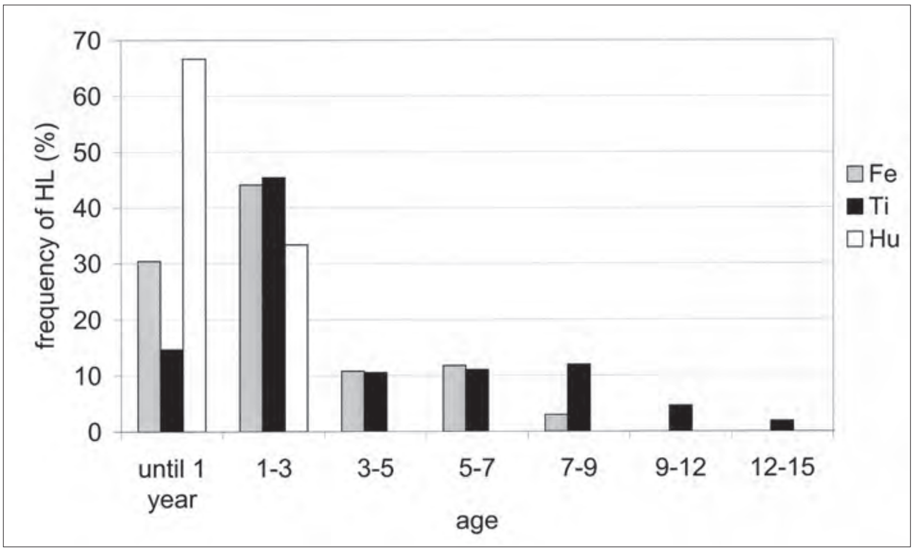
The high incidence of HL on the tibia is apparent even on the basis of the descriptive statistics summarised in table 5. This is especially clear if we focus on the median, which in the case of the tibia reaches a value of 3, in the case of the femur a value of 1 and is actually zero in the case of the humerus. The maximum recorded incidence of lines on a single bone– on its proximal or distal part – was eight, again in the case of the tibia.

Table 5. Descriptive statistics.

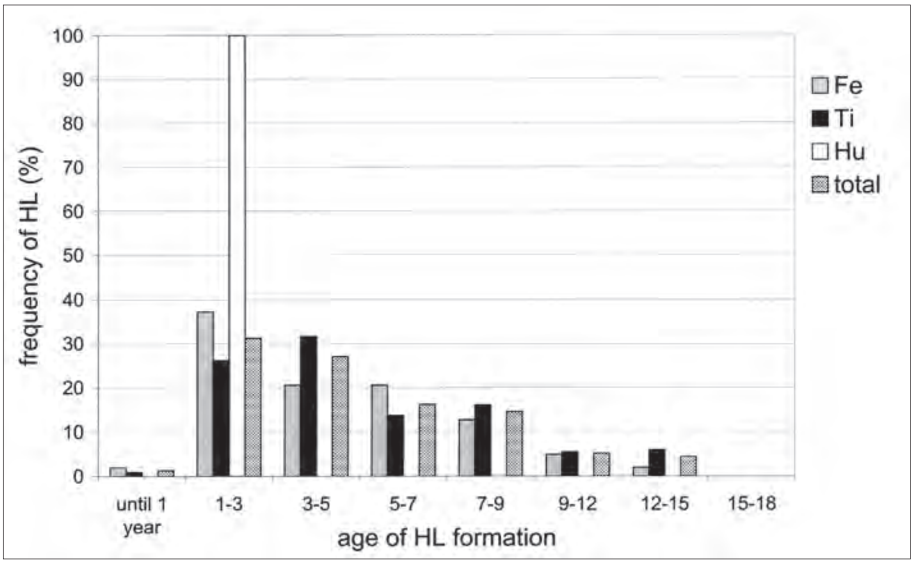
	Fe	Ti	Hu	Total
Mean	1,0	2,9	0,1	2,7
Standard error	0,1	0,2	0,0	0,2
Median	1	3	-	2
Mode	-	2	-	-
Standard Deviation	1,1	2,0	0,3	2,8
Maximum	6	8	2	13
N of HL	102	218	6	326
Valid N	106	75	94	122
HL/individual	0,96	2,91	0,06	2,67

As expected, with increasing age (age at death), we observed a decrease in the number of lines formed. The age distribution of HL is presented in Graph 2a.

As to the period of HL formation, the greatest number of lines, more than 40%, developed between the 1st and 3rd year of an individual's life. This applied to all the bones studied (Graph 2b).



Graph 2a. Frequency of HL in individual age groups.



Graph 2b. Distribution of HL by age of HL formation.

According to the results obtained, and on the basis of McNamara's test, we were also able to prove the hypothesis that HL occur symmetrically on the right and left side of the body. We monitored this side symmetry only in the femur and tibia, as the frequency of HL on the humerus was too low.

We evaluated the intra-observer error and inter-observer error of measurement in order to verify the method's objectivity. Based on the results of the Friedman's ANOVA by ranks, it is possible to consider the method of HL evaluation as objective and the deviations as statistically insignificant.

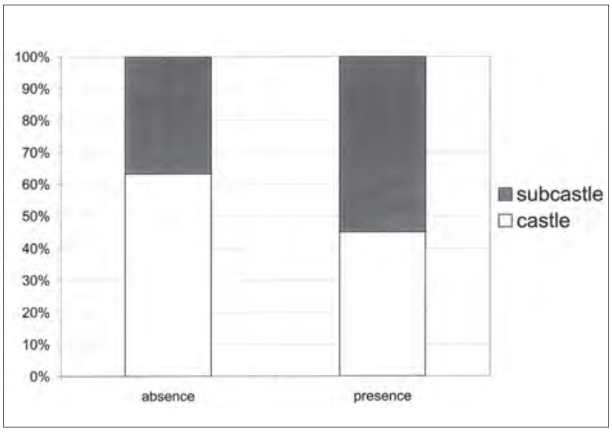
Table 6. Occurrence of HL according to grave equipment.

	Grave Equipment	N of ind. with HL	Total Individuals	% ind. with HL
Unzeitigová 2000	1st group	13	18	72,2
	2nd group	11	14	78,6
	3rd group	65	90	72,2
Stloukal 1970	1st group	17	23	73,9
	2nd group	72	99	72,7

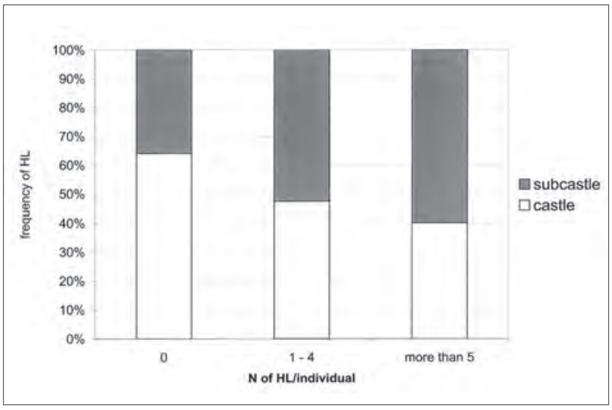
We used the χ^2 test to determine the distribution of HL in individuals buried within the castle or in the sub-castle area. As we could not reject the zero hypothesis regarding the uneven distribution of lines at neither the 0.05 nor the 0.01 level, our assumption that a lower incidence of HL reflects better living conditions in one of the studied populations was not confirmed (Graph 3a).

We also used the same statistical methods for evaluating the differences in the incidence of HL in individuals with different grave equipment. Similarly, in this case we did not record any significant differences between the individual categories. We rejected the zero hypothesis at a level of 0.9, which was not statistically significant (Graph 3b).

Table 6 includes more detailed information regarding the distribution of HL according to grave equipment.



Graph 3a. Distribution of HL according to the location of the burial ground – castle and sub-castle.



Graph 3b. Distribution of HL according to burial grounds, taking into account the number of HL per individual.

5. Discussion and conclusions

Harris lines were discovered on certain of the studied bones (femur, tibia, humerus) in more than 70% of non-adult individuals (89 of 122). As presumed, the highest incidence of HL was on the tibia (in nearly 90% of individuals). Occurrence on other bones was considerably less frequent, whereby HL were observed on the femur in 55% of cases and we detected only 6 lines (5%) in the case of the humerus.

These results thus confirm the conclusions of previous studies. It is well known that long bones are "most suitable" for the study of HL (Biukstra/Ubelaker 1994), especially the bones of the lower limb – tibia and femur. Thanks to the more rapid growth of the bones of the lower limb, the distance between the lines increases and the HL are thus more amenable to observation and evaluation (Elliot/Souther/Park 1927; Park 1964; Hunt/Hatch 1981). According to many previous studies, the highest incidence of HL has been recorded on the distal part of the tibia, followed by the proximal part of the tibia, the proximal part of the femur and the distal part of the radius. Thus, the tibia is the most suitable as well as the most frequently used bone for the study of HL, in view of the highest incidence of HL (Gindhart 1969; Hummert/Van Greven 1985; Vyhnánek et al. 1986; Huges/Heilings/Power 1996; Ubelaker/Pap 1998).

The different incidence of lines on long bones has long been the subject of much deliberation. It may be presumed that these differences are due to the different sensitivity or resistance towards the same stress event (disease, malnutrition, etc.). In other words, individual bones have a varied sensitivity threshold to the effects of non-specific stress (Hummert/Van Greven 1985). For example, for HL to develop on the femur, the effect of such stress must last for a longer period of time and must be more intense than in the case of the tibia.

The lower limbs are permanently exposed to the effects of great stress given their biomechanical function during locomotion and the impact of the weight of the trunk. From this aspect, the higher incidence of HL on the tibia is more difficult to interpret, as the section of the body exposed to the greatest stress is the hip (Dylevský/Druga/Mrázková 2000). The development of a higher number of lines in the case of the tibia may be explained by an enhanced reaction of this bone even to short-term stress events, rather than by long-term constant stress. As mentioned above, the subsequent termination of the stress event is important for the development of HL. A greater number of short-term stress situations may thus consequently lead to the development of a greater number of lines.

Although in the past decades the study of Harris lines has received much attention, nearly no similarly dated and geographically close comparable material exists. Only a few studies exist, most of them involving the tibia. If we compare the incidence of HL on this bone, the results are quite similar. The first two studies relate to the same locality of Mikulčice. At the Mikulčice-Kostelisko (sub-castle) burial site, where both adults and children were evaluated, 86.7% of individuals were recorded to have HL (Velemínský 2000). At the Josefov burial site, within the Mikulčice zone, over 80% of individuals had HL (Stránská et al. 2002). Other evaluated burial sites were located in Poland. At the burial site in Cedynia, HL occurred in 86% of individuals (Piontek/Jerszynska/Nowak 2001), or rather 68% if only children were evaluated (Jerszynska 1991). 81% of non-adult individuals with HL were recorded at burial sites near the St. Jacob and St. Christopher churches in Wroclaw (Gronkiewicz et al. 2001). A similar incidence was recorded in differently dated and geographically located populations (e.g. Manzi et al. 1989). In view of the demonstrated and frequently studied resorption lines in later age due to bone re-modelling (Garn et al. 1968; Marshall 1968; Gindhart 1969), the number of individuals with HL in the older population may be significantly lower. The decreased incidence of HL in a recent series of 160 adult men aged between 49 and 88 (average 67.3) who survived World War I is also apparently related to resorption. Lines were recorded on the tibias of only 22% of individuals (Vyhnánek/Stloukal 1991).

As mentioned before, lines are most frequently evaluated on the distal end of the tibia, usually only on one side of the body. The lines occur nearly regularly and symmetrically on both bones (Vyhnánek/Stloukal 1991; Grolleau-Raoux et al. 1997). The presence of an asymmetrical line that developed in another period than the line on the contralateral tibia is rare (Velemínský 2000; Stránská et al. 2002; Zítková 2003).

We also focused on the period of line formation. As mentioned in the methodology, we used that according to Byers (1991) for determining the age at which the lines formed. Byers created an ontogenetic model of the percentual growth increments of individual long bones in order to infer the period of HL formation. He based his model on four older ontogenetic studies (Anderson/Green 1948, Maresh 1955, Anderson/Green/Messner 1963, Gindhart 1973). The Byers model is designed separately for boys and girls. Optimally, ontogenetic conversion tables based on a geographically close and similarly dated population should be available for the subsequent evaluation of lines. From this aspect, the ideal study focuses on the growth of the long bones of limbs in the Great Moravian population (Stloukal/Hanáková 1978). The goal of this study was to enable the estimation of biological age from the length of the long bones of limbs in children. Unfortunately, the sexual differences in ontogenesis are not taken into consideration here, as no reliable method for determining sex on the basis of children skeletons exists.

In all the bones studied, the greatest number of lines developed in the period between the first and third year of life. This period approximately corresponds to that, when the quality of the children's diet changes as a consequence of weaning. The high number of lines that develop during this period is often explained by the so-called weaning hypothesis (e.g. LEWIS/ROBERTS 1997). Other studies, though, oppose this view. For example, the work of BLAKEY/LESLIE/REIDY from 1994, which studied the skeletal remains of African slaves from the 19th century. Although women were forced to wean their children as early as the 9th and 12th month, the greatest number of HL occurred in the period between the third and fourth year of life. The development of hypoplastic enamel defects is often associated with the weaning hypothesis (TREFNÝ/VELEMÍNSKÝ 2001).

Regardless of the cause of the development of these lines in a certain period, the results of our study are in accordance with the general premise that most lines develop by the 11th year of life (HATCH 1983). Certain studies, though, differ within this age range. While our work and several others (e.g. GINDHART 1969, GOODMAN/CLARK 1981, CARLI-THIELE 1996, STRÁNSKÁ et al. 2002) equally cite the age between one and four years as the period of the highest incidence of HL, according to other studies (JERSZYŃSKA/NOWAK 1996; VELEMÍNSKÝ 2000; PIONTEK/JERSZYNSKA/NOWAK 2001) these lines develop most often between the age of six and twelve. This may also be due to the different age characteristics of the given groups. Lines that developed earlier may be already resorbed in older individuals.

Finally, we focused on the relationship between the number of lines and the social status of the given individual. Social status was given by the localisation of the grave within the Mikulčice power centre (castle/sub-castle) and by the wealth of the grave equipment. We were unable to demonstrate such a relationship. The differences between the groups were not statistically significant. Nonetheless, if we look at Graph 3a and 3b, it is clear that the incidence of HL in individuals from the sub-castle area is "slightly" higher. This difference appears even more marked, if we divide the individuals according to the number of lines. The group of individuals without HL is more numerous in the castle, compared to individuals with more than five lines who predominate in the sub-castle The differences are not statistically significant, though. The reason for this may be the uneven distribution of lines at the burial sites of the castle and sub-castle, or the lower number of studied individuals from the sub-castle. It also cannot be ruled out that the differences in living conditions of individuals buried at various burial sites in Mikulčice were not as great as we presumed.

Similarly, we reached statistically inconclusive results when evaluating the relationship between the incidence of HL and the character of grave equipment. In this case, the onset of Christianisation in Great Moravia may have played a significant role, as this ushered a departure from pagan traditions such as the placing of gifts and offerings into the grave (STLOUKAL/VYHNÁNEK 1976). This fact may have led to the lessening of differences between the individual groups of the population.

It cannot be ruled out that HL do not completely reflect the social status and living conditions of individuals from past populations. The average incidence of HL in non-adult individuals is more or less the same in various populations.

Finally, we may conclude that our study unambiguously confirmed the highest incidence of HL on the tibia, especially its distal end. The incidence of lines on the humerus was negligible. This fact may be associated with the biomechanical and locomotory stress suffered by bones. We may also consider the intensity of lines and its relationship with the degree of stress suffered. Here again, though, we encounter the greatest shortcomings of HL evaluation – resorption lines as a consequence of bone re-modelling. The study of this sign is thus more ideal in a non-adult population. If we do not discover lines on the skeleton of an adult human being, we cannot claim that none developed. Another problem involves the as yet ambiguous aetiology of HL development, as highlighted by Patricia GINDHART´s (1969) work that studied the relationship between HL and disease in children. According to the results of this work, only 25% of HL develop as the consequence of a concrete disease. It is thus difficult to evaluate HL- a manifestation of undergone non-specified stress- as an independent indicator of the health status of past generations. Nonetheless, if we place HL in the context of other characteristics that reflect living conditions (e.g. cribra orbitalia or enamel hypoplasia, Velemínský/Dobisíková 2000), then they may contribute towards the study of the lives of our ancestors.

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Anthropological and epidemiological characterization of Great-Moravian population in connection with the social and economic structure

Proximal Femur Bone Density of the Great Moravian Population from Mikulčice Evaluated by Dual-Energy X-ray Absorptiometry

Jakub Likovský[1] - Petr Velemínský[2] - Vít Zikán[3]

Osteoporosis is the most frequent and most serious bone disease, which leads to the reduction in normally mineralised bone mass. For our study, we selected individuals from the burial sites in the vicinity of the I^st^, II^nd^ and III^rd^ church located within the grounds of the Mikulčice castle and from the Kostelisko burial site in the Mikulčice sub-castle area. In total, the proximal ends of the femur of 70 adult individuals were measured. The examination was conducted with the aid of dual X-ray absorptiometry (DXA) using the standard method with the QDR 4500 device from Hologic (USA). There was found a statistically significant difference only between the average Bone Mineral Density (BMD) values of males and females. BDM values of the Great Moravian population were higher both in males and females compared to the Hologic DXA Reference Data Based on NHANES III of the recent population. It may be concluded, if somewhat exaggeratedly, that the inhabitants of the Great Moravian Empire enjoyed better living conditions or health than the recent population. Similar results were also reached by other European institutions.

Key words: BMD – osteoporosis – DXA – Great Moravia – Early Medieval

1. Introduction

1.1 Osteoporosis and bone mineral density

The World Health Organisation defines osteoporosis as a progressive systemic disease of the skeleton, characterised by a reduction in bone mass, disorders of bone tissue micro-architecture and subsequent increased propensity of the bone to fractures (WHO 1994). Currently, osteoporosis is the most common and thus most serious metabolic bone disease. Osteoporosis fractures are a major cause of morbidity in the population.

A bone mass below average for age can be considered a consequence of inadequate accumulation of bone in young adult life (low peak bone mass) or of excessive rates of bone loss. Peak bone mass is usually achieved between 25-30 years of age and is primarily determined by genetic factors. Additional factors such as gonadal steroids, timing of puberty, low body weight at maturity and at 1 year of life, sedentary lifestyle and low calcium intake during childhood are important in the development of peak bone mass. The causes of bone loss in adulthood are multifactorial, because bone mass is influenced by patterns of physical activity, lifestyle and dietary factors such as calcium intake, vitamin D as well as by exposure to toxic agents.

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Bone mineral density (BMD) is the single best predictor of osteoporotic fracture risk and explains about 80% of the variability in bone mechanical resistance (Lauritzen et al. 1996). However, mechanical resistance of the bone depends not only on BMD, but also on bone microarchitecture and bone geometry – length and width of the femoral neck and the femoral neck-shaft angles (Gnudi et al. 2002). BMD can be assessed with a variety techniques. Dual-Energy X-ray Absorptiometry (DXA) is the most widely used bone densitometric technique.

1.2 Osteoporosis and its complications

Osteoporosis has several causes. The term primary osteoporosis refers to idiopathic juvenile osteoporosis, idiopathic osteoporosis in young adults, and to involutional osteoporosis, which is the most frequent of all types of osteoporosis. It is usually classified according to Riggs (Havelka 1990) as type I – post-menopausal and type II – senile. Post-menopausal osteoporosis occurs more frequently in females aged 55-65, than in men, with a ratio of 6:1. Etiologically, hormonal changes (absence of oestrogens) play a key role in this type. Trabecular bones are affected more significantly and vertebral fractures predominate. Senile osteoporosis occurs after the age of 70, and the ratio of affected females to males is 2:1 (in females, though, the boundary between post-menopausal and senile osteoporosis is not completely clear). Etiologically, decreased levels of the active vitamin D metabolite and increased levels of serum parathormone together with decreased intestinal calcium absorption play a key role. Both trabecular and cortical bone are affected. Fractures of the axial and appendicular skeleton occur, with a predominance of fractures of the long bones and fractures of the femoral neck.

Secondary osteoporosis is caused by another, underlying disease. Apart from long-term immobilisation, these causes mainly include endocrine as well as gastrointestinal diseases, kidney disease or malignancies. Osteoporosis may also be induced iatrogenically, for example in association with the long-term administration of corticosteroids (e.g. Broulík 2001).

Osteoporotic changes are significantly associated with changes of bone function, especially with decreased mechanical robustness. This mechanical deficit is associated with a substantial risk of fractures that may occur even following relatively minimal stress. Osteoporosis is characterised by slow and often asymptomatic development, whereby the first symptom may be such a fracture (Broulík 2001). Common sites for osteoporotic fracture are the spine, hip, distal forearm and proximal humerus. Though fractures of the proximal femur are not frequent in archaeological skeletal samples, the more commonly detected fractures of the vertebrae, the distal end of the forearm and of the ribs, all have a clear relationship with fractures of the femoral neck in the current population (Aufderheide/Rodríguez-Martín 1998).

1.3 Study of the long-term trends in the development of osteoporosis

The clinical significance of osteoporosis lies in the fractures that arise much more rapidly than would be expected according to the demographic data relating to population ageing, especially in developed countries. Research shows that the European population is most affected, demonstrating the highest percentage of fractures (Turner-Walker/Mays/Syversen 2001).

Even within the European continent, there exist certain geographical differences in the prevalence of osteoporosis. Osteoporosis is most widespread in the northern regions of Europe and its incidence decreases southward. In the Czech Republic, a steep increase in osteoporosis-related fractures has been noted, compared to other European countries (Štěpán 1990). The causes of such a great increase in the incidence of osteoporosis and fractures have not as yet been clarified.

Most of the studies mapping the incidence of osteoporosis cover only a very short period of time in view of how long the human population is in existence (Melton/O'Fallon/Riggs 1987; Palvanen et al. 1998). The identification and recognition of the long-term trends of bone density development could help clarify the rising frequency of osteoporosis and thus of fractures in the current population. Consequently, such identification could contribute towards better prevention of this disease. The long-term trends in the development of osteoporosis are studied at some, mostly European, institutions. A number of authors have been involved in the monitoring of osteoporosis, especially in skeleton samples from the Middle Ages since the 1990s (Poulsen et al. 2001; Ekenman/Ericsson/Lindren 1995; Lees et al. 1993; Mays/Lees/Stevenson 1998; Mays 1999). Changes of proximal femur geometry, comparing pre-historical, historical and current populations, have also been the subject of studies (Anderson/Trinkaus 1998).

2. Material

The studied individuals came from the burial sites in the vicinity of the I[st], II[nd] and III[rd] church, located within the grounds of the Mikulčice castle (Stloukal 1963, 1967; Brůžek/Velemínský 2006) and from the Kostelisko burial site in the Mikulčice sub-castle area (Velemínský et al. 2005). It is very probable that both castle burial grounds served the rich classes, while it is expected that the poorer classes were buried at the Kostelisko site. On the other hand, archaeologists presume that the burial sites around the III[rd] church and Kostelisko have a similar socioeconomic status, compared to the hinterland burial grounds (Staňa 1997). Selection of these individuals depended on the preservation of their femurs. Only those individuals with both femurs intact were selected (Mazess 2000). Actually, femurs damaged in the area of the head, neck, both trochanters and the intertrochanteric crist were not included in the analysis. Each side of the femur was evaluated separately. Identifying the individual's gender was another criterion used in the selection. We also tried to take the individual's age at death into consideration, but it later became clear that although we worked with only three age categories – 20-35 years, 35-50 years and over 50 years – certain categories were not sufficiently represented to allow statistical evaluation. Finally, we took into consideration whether the given grave lay within Mikulčice within Mikulčice castle itself or within the Mikulčice sub-castle area, as well as the richness of the grave paraphernalia i.e. the social structure of the society (Poláček/Marek 2005).

In total, the proximal ends of the femur of 70 adult individuals – 66 females and 15 males – were measured. In the case of the females, the following graves were involved: 20, 21, 24, 35, 58, 92, 99, 144, 149, 151, 167, 173, 202, 214, 237, 239, 286, 304, 305, 348, 352, 369, 404, 412, 428, 503, 519, 558, 575, 602, 614, 625, 667, 671, 719, 739, 1576, 1578, 1592, 1600, 1605, 1608, 1615, 1636, 1640, 1648, 1680, 1707, 1725, 1775, 1814, 1818, 1820, 1831, 1832, 1835, 1909, 1924, 1938, 1963, 1973, 1998, 1777A, 659-465. The male skeletons included in the study came from the following graves: 130, 1573, 1599, 1784, 1792, 1794, 1809, 1821, 1837, 1854, 1860, 1861, 1908, 1912, 1945, 1980, 1989, 2003, 2005.

3. Methods

Not so long ago, decrease of BMD could be dedected only by using X-rays (Allison 1988, Vyhnánek 1999). A radiology exam is indicative of the diagnosis of osteoporosis only when the amount of bone mineral decreases by 25-30% (Siegenthaler et al. 1995; Štěpán 1990, 1997). Nowadays, bone densitometry using DXA is used on archeological material. In contrast to certain other methods, DXA is a non-invasive method, which is good for archaeological studies of bones (Roberts/Manchester 2007). Although, DXA has a number of restrictions when used in palaeopathology. These include, e.g. effects of burial, or post-mortem effects with loss of bone (Roberts/Manchester 2007).

Currently, in clinical practice, DXA is the most widely used diagnostic method in osteoporosis. The widespread clinical use of DXA, particularly at the proximal femur and lumbar spine, arises from

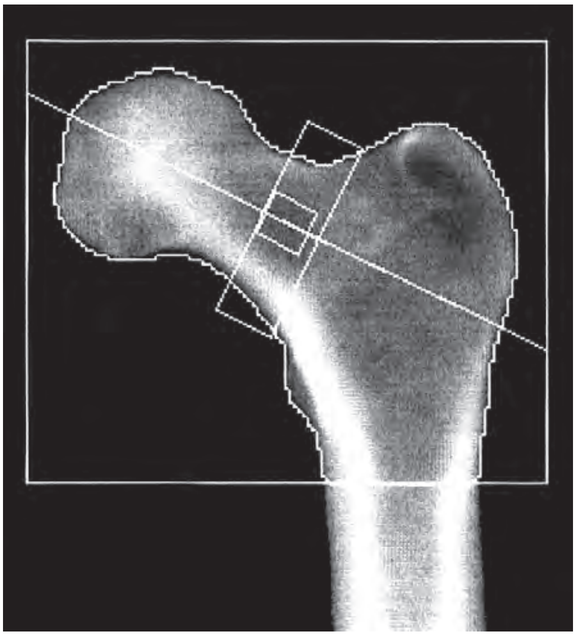


Fig. 1. Densitoetric examination of the proximal femur – the areas of interest (marked graphically)– the whole proximal end of the femur and the femoral neck).

many prospective studies that have documented a strong gradient risk for fracture prediction. This method is based on the utilisation of two defined radiation energy levels, thus eliminating the effect of radiation absorption in soft tissues that envelop non-homogenously the studied bone structure – e.g. the upper femur (Rosa 1999).

The state of bone density is studied not only on the proximal end of the femur, but also on the body of the lumbar vertebra or the second metacarpal. Similar results have been obtained in historical skeletons, where BMD was determined concurrently in several bones. Such an approach is illustrated by the medieval skeletons from Wharram Percy in Norton Yorkshire, England, in which the metacarpal index was measured using radiographs of the second metacarpal (Mays 1996) and, subsequently, DXA of the proximal femurs was conducted (Mays/Lees/Stevenson 1998).

During the archaeological study of bones using methods developed for the current "living" population, one of the problems is the simulation of the soft tissues that envelop the bone in living persons. From the various possibilities available, that using a standardly high layer of rice in which the bone is laid in a clearly defined position appears to be the most suitable (Mays 1999, Turner-Walker/Mays/Syversen 2001).

The examination itself was conducted at the Bone centre of the 3rd Clinic of Internal Medicine, the General Teaching Hospital and the 1st Medical Faculty of Charles University in Prague. BMD was determined on the proximal femur with the aid of double energy X-ray absorptiometry (DXA), using the standard method and the QDR Discovery device from Hologic (USA). For measuring, the femurs were placed in the standard position in a box filled with a 12.5 cm – high layer of rice, simulating soft tissue (e.g. Mays 1999; Turner-Walker/Mays/Syversen 2001). Each femur was measured twice, with reposition of the bone between measurements. For the analysis itself, we then used the average of the values measured in the area of the femoral neck, large trochanter and total femur region. The total femur region of interest encompasses all of the individual regions: the femoral neck, Ward's area, the trochanteric region and the shaft. In this method, the BMD gives an expression of bone mineral content (BMC) per area of bone projection into the picture plane (see. Fig. 1). The paired t-test was used after verification of the significance of differences of the compared groups.

In the adult population, BMD is divided statistically normally, and thus excessive BMD may be expressed as the standard deviation (SD) from the average measured in a population of young, healthy persons of the same sex (Štěpán 1997). In practice, BMD is expressed in T-score units. Every reduction of BMD by 1 SD (1 T-score) doubles the risk of fracture.

4. Results

Table 1 lists the actual average values of bone density measurements in g/cm^2 for the whole proximal end of the femur and for the femoral neck. These values are divided not only with regards to sex, but also with regards to the laterality of the femur.

Table 1. Mikulčice – the values of BMD of whole femoral end and only femoral neck (dx) with regard o sex nad side and Hologic DXA Reference Data for recent population (BMD, SD).

	Males			Females		
	sin	dx	Ref.Data	sin	dx	Ref.Data
N	14	15		55	53	
TOTAL						
Mean of BMD (g/cm^2)	1.1652	1.1224	1,01	1.0247	1.0387	0.8433
min	1	0.907	0.151	0.677	0.693	0.111
max	1.373	1.395		1.323	1.415	
Std.Dev.	0.1223	0.1237		0.1486	0.1493	
T-Score	1,821	1,58		0,6709	0.7906	
NECK						
Mean of BMD (g/cm^2)	1,0147	0.957	0.8808	0.8546	0.8772	0.8128
min	0.853	0.672	0.136	0.592	0.612	0.136
max	1.231	1.231		1.114	1.229	
Std.Dev	0,1259	0.129		0.1182	0.1194	
T-Score	1,4929	1,1867		0.0327	0.2865	

Table 2a. Mikulčice – the values of BMD of whole femoral end and only femoral neck (dx) with regard to sex, age and side.

	Males		Females			
	20-35	35-50	20-35	30-40	35-50	over 50
N	3	11	13	10	23	6
	TOTAL					
Mean of BMD (g/cm^2)	1.1087	1.1094	1.0533	1.0493	1.0352	1.0135
min	0.971	0.907	0.754	0.865	0.693	0.840
max	1.179	1.204	1.279	1.290	1.415	1.298
Std.Dev	0.096	0.1287	0.1471	0.1469	0.1477	0.1341
T-Score	1.333	1,3727	0.9076	0.89	0,76	0.5833
	NECK					
Mean of BMD (g/cm^2)	0.9460	0.9239	0.9034	0,8784	0.8666	0.8712
min	0.758	0.672	0.744	0,7100	0.697	0.707
max	1.069	1.109	1.193	1.111	1.229	1.035
Std.Dev	0.0996	0.1329	0.1162	0,1216	0.1189	0.1024
T-Score	0.9	0.9636	0.4769	0,4333	0.1695	0.2167

Table 2b. Mikulčice – the values of BMD of whole femoral end and only femoral neck (sin) with regard to sex, age and side.

	Males		Females			
	20-35	35-50	20-35	30-40	35-50	over 50
N	3	11	14	10	24	5
	TOTAL					
Mean of BMD (g/cm^2)	1.0517	1.1592	1.0294	1.0188	1.0088	1.0996

	Males		Females			
	20-35	35-50	20-35	30-40	35-50	over 50
min	0.875	1	0.69	0.847	0.677	0.874
max	1.143	1.314	I.29	1.245	1.309	1.323
Std.Dev	0.1012	0.1306	0.1489	0.1441	0.1439	0.1325
T-Score	0.9	1,7727	2,80	0.62	0,5417	1,28
	NECK					
Mean of BMD (g/cm2)	0.9053	1.0119	0.8524	0,8743	0.8289	0.9428
min	0.732	0.869	0.595	0,6910	0.592	0.771
max	1.039	1.231	1.083	0,9840	1.114	1.058
Std.Dev	0.1061	0.1281	0.1182	0,1189	0.1155	0.0951
T-Score	0.5	1,4727	0.0286	0,2400	0.225	0.84

Table 3. Mikulčice - the values of BMD transformed into z score of whole femoral end and only femoral neck (dx) with regard to sex nad side.

	Males		Females	
	sin	dx	sin	dx
N	16	19	65	58
	TOTAL			
Mean of BMD (g/cm^2)	2,338	2,137	1,011	1,116
min	0,7	-	-1,9	-1,4
max	4,2	4	3,6	4,5
Std.Dev	0,952	0,953	1,278	1,288
	NECK			
Mean of BMD (g/cm^2)	2,188	1,711	0,609	0,779
min	0,4	-1,2	-1,9	-1,2
max	4,3	3,8	3,5	3,2
Std.Dev	1,084	1,096	1,168	1,176

Table 4. The comparison Great Moravian population with Norwegian and English Mediaeval skeletons (Mays et al. 2001) on the base the BMD of femoral neck.

		BMD at the femoral neck (g/cm^2)		
		Great Moravian population	Mediaevel Norway	Mediaeval England
Female	18-29 yrs	0.903	0.953	0.951
	30-49 yrs	0.867	0.783	0.808
	50+ yrs	0.871	0.702	0.724
Male	18-29 yrs	0.946	0.981	0.988
	30-49 yrs	0.924	0.886	0.934
	50+ yrs	-	0.828	0.826

In total, the proximal femurs of 60 adult individuals were measured – 55 females and 15 males. Regardless of the age at death, the average bone density in g/cm^2 (BMD) in the whole proximal right femur was 1.039 (SD 0.149) in females, and 1.122 (SD 0.124) in males. As for the left femur, it was 1.025 (SD 0.149) in females, and 1.165 (SD 0.122) in males. Femoral neck BMD values were as follows: females 0.86 g/cm^2 (SD 0.12) and males 0.94 (SD 0.13).

A statistically significant difference was shown between the average BMD values in males and females, both in the case of the whole proximal femur ($p < 0.01$), and in the case of the femoral neck BMD (dx = $p < 0.05$, sin = $p < 0.01$)

We worked with three age groups – 20-35 years, 35-50 years and over 50 years. The results are summarised in Tables 2a, b. The average value of bone density in g/cm^2 in females younger than 35 years (N=13) for the whole proximal end of the right femur was 1.053 (SD 0.147), for the femoral neck 0.903 g/cm^2 (SD 0.116). In the age group of 30-40 years (N=10), the average value of bone density of the proximal end of the right femur was 1.049 g/cm^2 (SD 0.147), and that of the femoral neck was 0.878 g/cm^2 (SD 0.122). Finally, in the largest group of females, those aged 35-50 years (N=23), the average value of bone density of the proximal end of the femur was 1.035 g/cm^2 (SD 0.148), and that of the femoral neck was 0.867 g/cm^2 (SD 0.119). Our group included only six females whom we presume to have died aged over 50. BMD values of the left femurs were similar in the individual age groups, or slightly lower. If we look at the BMD values of the whole femur end and of the femoral neck, it is clear that these more or less decrease with increasing age. The differences, though, are not statistically significant. In males aged 35-50 years (N=11), the average value of the bone density of the whole proximal end of the right femur was 1.109 g/cm^2 (SD 0.129), and that of the left femur was 1.159 g/cm^2 (SD 0.131). In the case of the femoral neck, these values were 0.924 g/cm^2 (SD 0.133) and 1.012 g/cm^2 (SD 0.128) respectively. The group of males younger that 35 is represented by only three individuals. Males who reached an age over 50 were not present in this group. No statistically significant differences were found between the age groups. However, the results may haven been influenced by the rather low number of individuals assessed.

From Tables 1, 2 it is clear that the bone tissue (mineral) density of the proximal femur is higher than that of the femoral neck, regardless of gender, age group or laterality. The BMD values of the femoral neck are on average lower by 0.15 g/cm^2 ($p < 0.01$). No statistically significant results were found between the BMD values of the right and left femurs.

5. Discussion

From the aspect of the incidence of osteoporosis, only one skeleton group has been examined in the Czech Republic– adult individuals from the burial site on Chelčického Square in Žatec, dating from the 11th-13th century (Likovský 2005). Although 265 individuals from this burial site were examined anthropologically, only 32 individuals of determined age and sex – 15 females and 17 males – remained for bone density evaluation, once femurs damaged in the area of the head, neck, trochanters and intertrochanteric crist were excluded. Only two age groups could be used in the evaluation – individuals who died before the age of 30 and individuals older than 50. The possibilities of interpreting the results of such a small group are quite restricted. Moreover, there was a significant variance among the values measured in young individuals.

The BMD values of this group did not essentially differ from those of the Mikulčice population. In the most represented group of males aged over 50 (N = 13), the average density value of the whole proximal end of the femur was 1.20 g/cm^2 (SD 0.15) and that of the femoral neck was 0.97 g/cm^2 (SD 0.11). Both values were statistically non-significantly higher than those of the analogical BMD values of Great Moravian males aged 35-50 years. In the population sample from Žatec, the density of bone tissue of the proximal end of the femur was also altogether higher than that of the femoral neck, but the difference in values was statistically significant only in females over the age of 50. The differences between the BMD values of both sexes were statistically significant (Likovský 2005).

If we do not take into account Central Europe, then the bone density of the proximal femur has been evaluated mainly in the medieval populations of Northern and Western Europe (e.g. Mays 1999, Mays/Turner-Walker/Syversen 2005, 2006). There definitely are not too many studies dedicated to this issue. If we compare, for example, the Great Moravian BMD values with those determined in medieval skeletons from burial sites in Trondheim, Norway and Wharram Percy, England, then the Mikulčice females have a slightly higher BMD (by approx. 0.1-0.05). This applies to all age categories, with the exception of the youngest. This, though, may be due to the fact that in the Great Moravian group, the lowest age category was defined somewhat more widely, from 18-34 years, while in the Norwegian/English population it was only 18-29 years. On the contrary, the following age category in the Great Moravian population was 5 years shorter at 35-49, compared to 30-49 years (Table 4). The BMD values of Mikulčice males were lower in both comparable age groups, compared to the BMD values of males from the English burial site at Wharram Percy. Compared to the Norwegian medieval population, these values were higher in males in the age category of 30-49 years, while in males in the age category of 18-29 years, BMD values were lower. Nonetheless, these results may again be influenced by the different definition of the age groups (Mays/Turner-Walker/Syversen 2005).

If we compare our results with the reference BMD data from the recent population (Hologic DXA Reference Data Based on NHANES III; Caucasian Female and Male), the Great Moravian population BMD values are clearly higher both in males and females (Bonnick/Miller 2004) (see Table 1). This applies especially in the case of BMD values of the total femur. The difference in BMD values of the femoral neck in females is no longer statistically significant. For comparison with the current population, it is to some extent possible to also apply the so-called z-score BMD values ($BMD_{z\text{-}score}$) (see Table 3). The BMD of medieval bones ($BMD_{medieval}$) are transformed into z-scores using the formula:

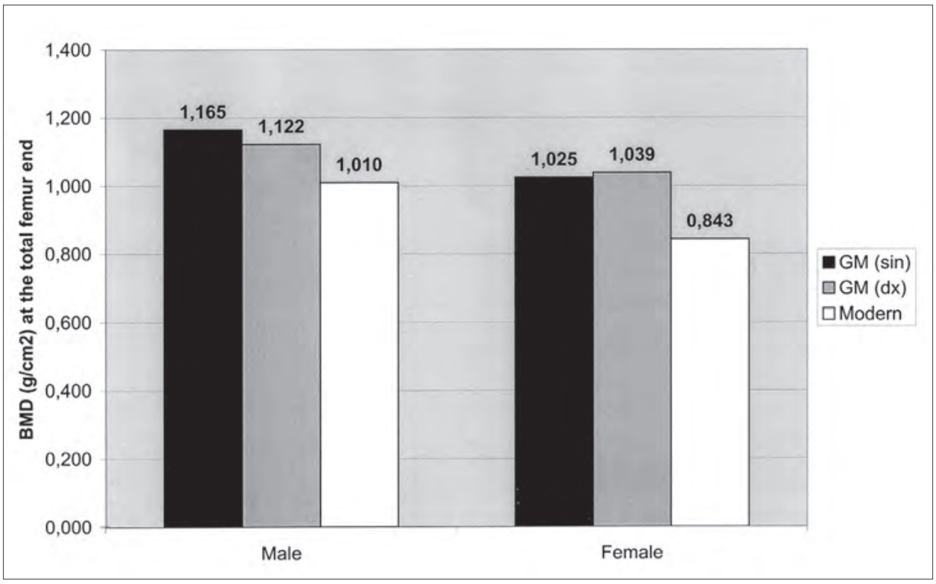
$$BMD_{z\text{-}score} = (BMD_{medieval} - BMD_{contemporary}) / SD_{contemporary}$$

. $BMD_{z\text{-}score}$ values correspond to the results, if we compare the Mikulčice BMD values with the Hologic DXA Reference BMD Data from the recent population. From this aspect, it may be concluded, though this may appear exaggerated, that the residents of the Great Moravian Empire had better living conditions than the recent population.

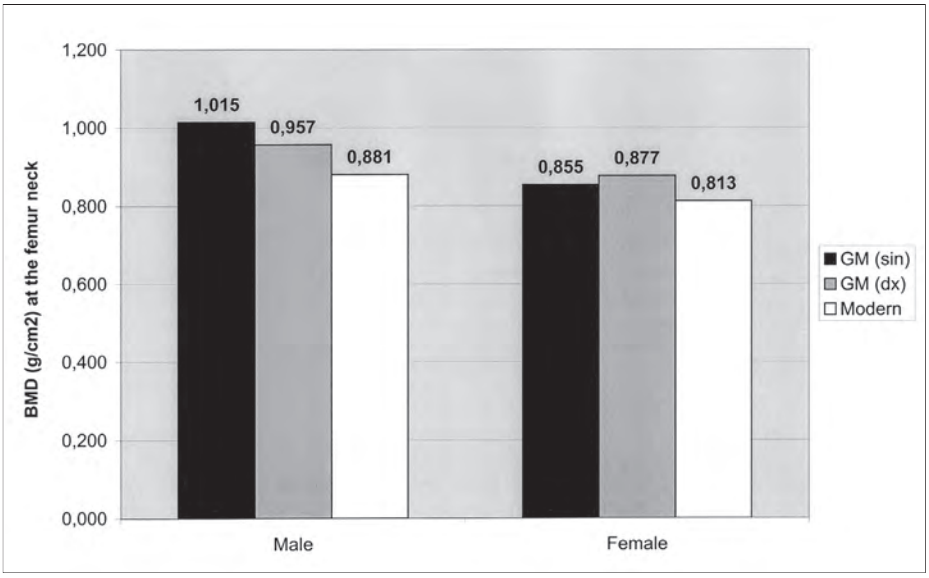
The BMD values measured in the Žatec -Chelčického Square were as a rule also above the norm for the current population group (Likovský 2005). Similar results were also reached by other European institutions (e.g. Ekenman/Ericsson/Lindgren 1995).

The Poulsen et al. (2001) study cited above showed that medieval females had lower BMD compared to contemporary females, but this relationship was reversed in females who survived into older age. In contrast, medieval males had significantly higher BMD compared to contemporary males at all ages. Authors explain the observed lower BMD in medieval females by the well-known selective mortality among younger females. A high birth rate and prolonged periods of lactation are the main reasons for the observed increased mortality, and therefore can also very likely explain the associated low BMD. The increase in the incidence of osteoporosis in modern elderly females could possibly, or partially, be explained by the survival of females who would have died prematurely had they lived in earlier centuries (Poulsen et al. 2001). Another study involving medieval populations from Norway and England reached similar conclusions (Turner-Walker/Mays/Syversen 2001).

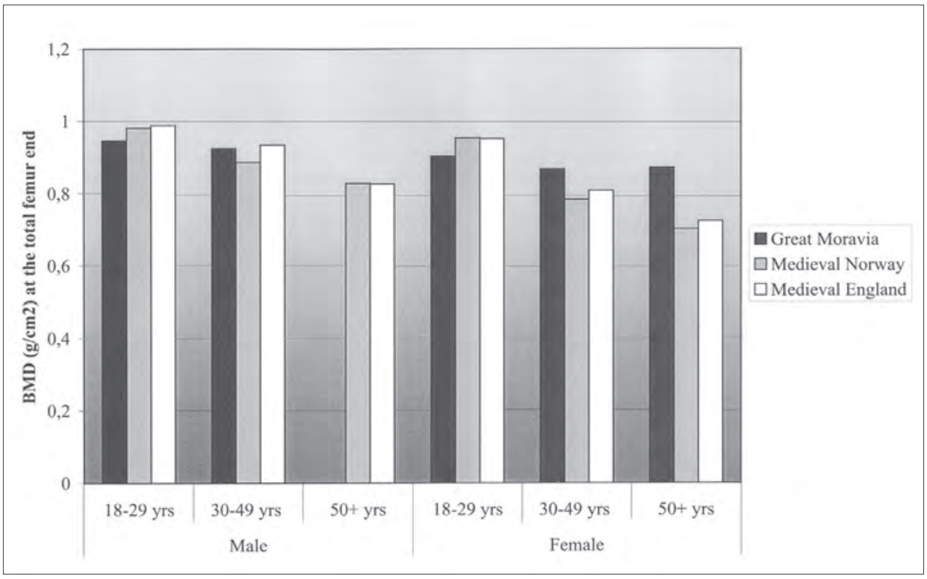
Correlation of BMD values with age, more precisely their decrease with increasing age, valid for the current population has been shown by a number of works. For example, research involving the burial sites in Trondheim, Norway and Wharram Percy, England reached analogical conclusions (Mays/Turner-Walker/Syversen 2005, 2006). On the other hand, another Danish study found that medieval females of



Graph 1a. The comparison of medieval Great-Moravian and recent populations on the base BMD at the whole femur end.



Graph 1b. The comparison of medieval Great-Moravian and recent populations on the base BMD at the femur neck.



Graph 2. The comparison of medieval Great-Moravian, Norway and English populations on the base BMD at the femur neck.

a lower age category showed lower BMD, while bone mass increased with age in older females. This, though, did not apply to males (Poulsen et al. 2001).

In other studies, BMD values similar to those of the current population were recorded. Given that great difference in lifestyles as well as lifestyle factors are widely held to influence the severity of bone loss in osteoporosis, the similarities between medieval and modern populations in the patterns of bone loss are surprising. (e.g. Mays/Lees/Stevenson 1998). This may be a case of a population specific phenomenon, and the results may also be related to the method of evaluation – the technique of BMD measurement in the femur and the "adequate" simulation of soft tissue.

Moreover, generally, pathological conditions that reduce bone density, such as osteoporosis, also reduce the ability of bones to resist decomposition. Osteoporosis is thus one of the causative factors of fractures (e.g. Leppälä et al. 1999). The incidence of osteoporosis is most often associated with fractures of the femoral neck, radial Colles' fractures and vertebral compressive fractures (e.g. Brickley 2002; Mays/Turner-Walker/Syversen 2006). We did not find any osteoporosis-related femoral fractures or Colles' fractures in our evaluated sample. Also, we did not evaluate vertebral fractures.

We also tested the degree of correlation between bone mineral density (BMD) and certain traits considered to be manifestations of environmental stress. For example, no relationship was found between BMD and the presence or absence of Harris lines or cribra orbitalia (e.g. McEwan/Mays/Blake 2005).

The basic problem of proximal femur bone density studies in previous populations is the lack of a "norm" for the bone density of the given previous population, to which it would be possible to relate the acquired results. This means that the interpretation of the acquired results is problematic. One must realise that the clinical studies with which we attempt to compare our observations deal with a living population. Moreover, norms are drawn up based on a healthy population. Works studying historical material operate with the dead, and if we cannot prove that sudden death occurred in a completely healthy individual (e.g. violent death), we must take into account that the individual in question suffered from a chronic underlying disease that may have affected the mineral concentration in bones.

6. Summary

The skeleton is metabolically active and bone remodeling occurs throughout life. Currently, osteoporosis is the most frequent and most serious bone disease, which leads to the reduction in normally mineralised bone mass. This is a progressive systemic disease of the skeleton, characterised by a decrease in bone mass, disorders of bone tissue micro-architecture and the subsequent increased propensity of the bone to fractures (WHO 1994). The clinical symptoms of osteoporosis in the current population are increasing much more rapidly than would be expected based on demographic data related to population ageing. Understanding the long-term trends of bone density development is one of the possible means of clarifying the rise of osteoporosis and thus of fractures in the current population. Thus, a number of authors have been monitoring osteoporosis since the 1990s. Medieval skeletal samples have been studied especially (Poulsen et al. 2001; Ekenman/Ericsson/Lindgren 1995; Lees et al. 1993; Mays/Lees/Stevenson 1998; Mays 1999).

For our study, we selected individuals from the burial sites in the vicinity of the Ist, IInd and IIIrd church located within the grounds of the Mikulčice castle (Stloukal 1963, 1967; Brůžek/Velemínský 2006) and from the Kostelisko burial site in the Mikulčice sub-castle (Velemínský et al. 2005). Selection of these individuals depended on the preservation of their femurs. In total, the proximal ends of the femur of 70 adult individuals – 66 females and 15 males – were measured. The examination was conducted with the aid of dual X-ray absorptiometry (DXA) using the standard method with the QDR 4500 device from Hologic (USA). For measuring, the femurs were placed in the standard position in a box filled with a 12.5 cm-high layer of rice, simulating soft tissue (e.g. Mays 1999; Turner-Walker/Mays/Syversen 2001).

The results may be summarised as follows:

- a statistically significant difference was only found between the average Bone Mineral Density (BMD) values of males and females
- no statistically significant difference was found between the average BMD values of the individual age groups
- no statistically significant difference was found between the average BMD values at the whole femur end and the femoral neck
- BDM values of the Great Moravian population were higher both in males and females compared to the Hologic DXA Reference Data Based on NHANES III of the recent population. It may be concluded, if somewhat exaggeratedly, that the inhabitants of the Great Moravian Empire enjoyed better living conditions or health than the recent population.

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Anthropological and epidemiological characterization of Great-Moravian population in connection with the social and economic structure

Frequency of Fractures of the Locomotor Apparatus at the Burial Sites in the Area of the Castle in Mikulčice

Jakub Likovský[1] – Petr Velemínský [2]– Lumír Poláček[3] – Jana Velemínská[4]

The goal of our study was to verify the frequency of injuries to the bones of the locomotor apparatus in a population group buried on the territory of the castle of the Great Moravian power centre at Mikulčice. The method of evaluation is based on the method of five segments, but we took the diaphyses of long bones to be a single segment, and we also evaluated the bones of the pectoral girdle of the upper extremities and the pelvis. In group of juvenile individuals no fracture was recorded on the studied bones. Adults represented a total of 531 individuals. In the whole group, a total of 59 fractures were recorded. There were 42 individuals with fractures - individuals with fractures represented 7.91% of the population. In the group of females were 8 fractures recorded in a total of 217 individuals – this represented 3.69% of individuals in the population of females; in the group of males a total of 31 individuals with a total of 43 fractures were uncovered – males with a fracture represented 10.83% of this group. The difference in the frequency of fractures between males and females was significant at the 1% level of significance. The frequency of fractures of the clavicle was statistically significantly higher compared to the other bones only in the case of the least affected femur and tibia. The prevalence of fractures of the radius was slightly higher than that described in studies focusing on British skeletal groups from the High Middle Ages. The overall higher frequency of fractures may be explained, for example, by the natural conditions of the locality..

Key words: palaeopathology – fracture – trauma – Great Moravia – Early Medieval

1. Introduction

1.1 Evidence of fractures in archaeological skeletal material

Signs of skeletal injuries and trauma represent – along with degenerative changes – the most frequently described pathological findings in anthropological literature dedicated to past populations. Descriptions of the consequences of injuries and trauma may be found in skeletal findings from all periods – from the Palaeolithic Age to the Modern Age. Signs of injuries or trauma have been described practically in all anthropologically researched skeletal burial sites (see e.g. the summary of palaeopathological findings on the territory of Czechoslovakia Hanáková/Vyhnánek 1981, the palaeopathological findings from the anthropological collection of the Institute of Archaeology in Prague (Likovský/Stránská/Velemínský 2005). This also applies to the Great Moravian burial sites at Mikulčice (Stloukal/Vyhnánek 1976; Velemínský 2000; Velemínský et al. 2005). Most often, though, this only involved

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case reports, which were not correlated with the number of individuals and the state of preservation of the skeletons or individual bones.

The localisation of injuries on the skeleton may hint at the living conditions and lifestyle, the type of work conducted, as well as the mechanism of injury itself. Differences may be expected between the sexes, between individuals of various social rank, between populations of various eras and cultures.

Post-traumatic states may also give a clue as to the level of "medical care" in the past. The quality of the treatment of injuries may be evaluated according to the manner, in which the fracture has healed, with a smaller or greater dislocation of the fragments given by the method of fixation. Or according to the frequency, manner of execution and percentage of healing of true surgical procedures, conducted most often after trauma, and exemplified on the skeletons in the form of amputations of extremities or post-traumatic trepanation of skulls with the extraction of bone fragments.

1.2 Classification of trauma

Traumatic changes of the skeleton may be assessed from several aspects – this has been repeatedly described in both medical and anthropological literature; especially in textbooks (e.g. Steinbock 1976; Aufderheide/Rodríguez-Martín 1998; Vyhnánek 1999; Horáčková/Strouhal/Vargová 2004; Roberts/Manchester 2007). According to the physiological state of the bone, fractures are classified as traumatic, induced by force acting on healthy bone and exceeding its mechanical properties of pressure, torsion or flexure (this group includes most of the accidental and deliberate injuries) and pathological, induced by normal stress on a bone weakened by a pathological process (most often associated with metabolic disease – osteoporosis, or malignant lesions).

From the aspect of trauma occurrence, we differentiate whether the cause was an accident, or if the injury was deliberate. Accidental injuries occur during routine human activities – careless handling of instruments and tools, falls. Deliberate (intentional) injuries mainly include those caused by weapons – slashes, stab wounds (e.g. Stloukal/Vyhnánek 1976; Vyhnánek 1999), wounds caused by a blunt object (Likovský/Drda 2003). Slash wounds are most often found on skulls, but may also appear on the diaphyses of long bones – the course of the line here corresponds to the horizontal position of the bone during the injury and is often attributed to injuries incurred by riders or horsemen (Stloukal/Vyhnánek 1976).

A very peculiar category is represented by so-called stress fractures that are induced by long-term stress and strain, and are most frequently located in the area of the metatarsi– these mainly involve small fissures, which are often difficult to detect (e.g. Koudela et al. 2002; Horáčková/Strouhal/Vargová 2004).

According to the extent of bone damage, we divide fractures into complete and partial – incomplete fractures involve only the partial fracture of the bone or the formation of cracks. The most frequently used classification of fractures involves their division according to the course of the fracture line and differentiates between transverse, oblique, longitudinal, spiral and splintered fractures. Transverse fractures are caused by a relatively small force acting on a small surface and the resulting fracture line is perpendicular to the longitudinal axis of the bone. The oblique fracture line is most frequently caused by direct force acting at an angle or rotationally. In contrast to oblique fractures, spiral fractures rotate around the bone's longitudinal axis (e.g. Bednář et al. 1984; Lovell 1997).

1.3 Injuries of the locomotor apparatus

Injuries of the locomotor apparatus may occur randomly, by accident, but these injuries may also be intentional or deliberate (see the aforementioned injuries of riders), or they may occur in self-defence – this is mainly associated with the bones of the forearm – so-called reflexive fracture or parry fracture (Vyhnánek 1999).

The following brief overview of the most frequent fractures and the mechanism of their development shows that in a number of cases it is difficult to differentiate between accidental and deliberate injuries.

1.3.1 Fractures of the pectoral girdle bones and the long bones of the upper extremity.

Fractures of the clavicle are considered to be frequent and usually occur indirectly by falling on an extended upper extremity or due to a direct impact on the area of the shoulder. These fractures occur most frequently (approx. 76%) in the middle section or (approx. 20%) in the lateral third of the diaphysis (Višňa/Hoch 2004; Pokorný et al. 2002). Their incidence is said to be higher in males and more often the left clavicle is involved (Stloukal/Vyhnánek 1976). Injuries of the scapula most often occur concomitantly with fractures of the humerus, clavicle or chest.

The humerus may be fractured in the region of its proximal end – fractures of the so-called surgical neck occur during falls and osteoporosis is usually a predisposing factor. In the region of the diaphysis, fractures occur due to direct intense force (a fall or violent strike on the arm). In the region of the distal epiphysis, fractures are most often localised supra-condylarly, or they are Y-shaped (during falls on a dorsally flexed arm or on the area of the elbow – when the olecranon ulnae is injured concurrently), most often in the supra-condylar area.

Besides fractures of the clavicle, fractures of the bones of the forearm are considered to be the second most frequent localisation of fractures. Their classification (Colles, Smith, Barton's, Monteggi, Galleazi fractures etc.) is based on the mechanism of injury. In fractures of both bones of the forearm (due to a fall on the extended arm or due to a direct strike), the fracture line usually runs in the middle of the diaphysis. Isolated fractures of the ulna usually occur during the defensive holding out of the forearm.

1.3.2 Fractures of the pelvis and the bones of the lower extremities.

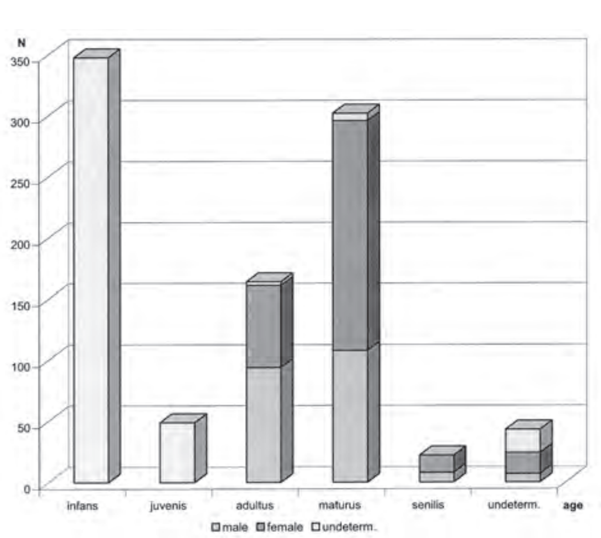
Fractures of the pelvis that usually occur by falling directly on the pelvis or indirectly by transfer of force during falls on both feet from a height are – perhaps with the exception of partial fractures involving the pelvic bone projections – serious, life-threatening injuries, often associated with other trauma. Practically, all the pelvic bones may be broken (the ilium, ischium and pubis). Apart from this, fractures in the area of the hip joint socket due to the transfer of force across the femoral head. The most frequent fractures are those involving the rami of the pubic bone (see e.g. Hoffa 1896).

Fractures of the femur most often occur in the area of the proximal end – the area of the neck and trochanters. These fractures are typical for skeletons affected by osteoporosis and their rising numbers currently represent a worldwide problem (e.g. Štěpán 1990) (see Likovský/Velemínský/Zikán this book, pp. 223-234). It is reported that fractures of the per-trochanteric area are so typical that they can be distinguished in skeletal material even in cases where healing failed to occur (Vyhnánek 1999). Fractures of the femoral diaphysis, if bone continuity is interrupted, may be extremely dislocated due to the pull of muscles and may heal with a significant callus – they thus rank among the most conspicuous pathologies on the skeleton. Fractures of the femoral distal epiphysis occur due to a fall or strike on the flexed knee. In such cases, the condylar or supra-condylar area is injured.

Fractures of the tibia are most frequently diaphysar, and they occur with nearly the same frequency in both sexes (Vyhnánek 1999). 20% of cases involve open fractures, which may easily lead to infectious complications of the injury. A depressive fracture of the lateral condyle is characteristic for the proximal epiphysis of the tibia. Fractures of the diaphysis – most often spiral – are usually associated with a fracture of the neck of the fibula, for which the most characteristic fracture is that in the area of the distal end-lateral ankle (malleolus).

1.4 Diagnostics of fractures in archaeological skeletal material

The limiting factor of the evaluation of archaeological skeletal remains is, on one hand, the completeness of the individual skeletons,



Graph 1. Basic demographic structure of the Mikulčice castle population.

and on the other the state of preservation of the bones in question. Naturally, the completeness and preservation of skeletons also dictate the possibility of identifying and evaluating traumatic changes.

The basic problem of evaluating injuries is the ability to distinguish the unhealed post-traumatic state from post-mortem damage to the bone. With the exception of those cases, where there is an unequivocal mark of the instrument (weapon or sharp object) that caused the injury, post-mortem damage and (non)deliberate force cannot be distinguished with certainty. Even in those cases where the course of the fracture line corresponds to a type of fracture known in clinical practice and where it would be possible – if an old fracture line is uncovered – to consider a fracture incurred peri-mortem (Stloukal/Vyhnánek 1976), a certain degree of doubt remains.

Several authors have studied the possibilities of differentiating unhealed fractures from damage (e.g. Maples 1986). Nonetheless, even the study of recent skeletal material has shown that not even microscopy methods can demonstrate a fracture less than two weeks old (Mann/Murphy 1990).

Therefore, accidental, unintentional injuries can be studied in palaeopathology only if the fracture healed – a callus developed and the shape or axis of the bone changed. A fracture usually heals completely within 3-4 months from the injury (Bednář et al. 1984); if no complications occur – for example, infection at the site of injury, inadequate fixation of the fragments, necrosis. X-rays help in the correct assessment of the character of a fracture (see e.g. Vyhnánek 1999).

The frequency of fractures in the population has been studied by several authors in the past decades, and various methods of evaluation have been devised (for an overview see Roberts/Manchester 2007). Stress is placed on the relationship between the fractures and the true number of individual preserved bones (e.g. Müller et al. 1990; Grauer/Roberts 1996). Certain methods are capable of working with fragmented material (Judd 2002).

2. Materials

2.1 Selection of the population group

For our research, we have selected burial sites located within Mikulčice castle itself, where archaeologists presume the socially more powerful ranks of Great Moravian society are buried, i.e. including the burial of males – “warriors” (e.g. Poulík 1975). These burial sites include the one beside the second Mikulčice church (252 graves) and the one next to the three-nave basilica the largest church of the Mikulčice-castle (569 graves).

In our selection, from a demographic aspect, we also drew from the conclusions of Stloukal (1963, 1967) with a delimitation of both burial sites according to the extent known in the 1950s – i.e. burial site 1 (IInd church) and burial site 2 (IIIrd church). We then extended the results acquired (Likovský et al. in print) to include those of later explorations of a section of the necropolises (Poláček/Marek 2005). In total, the burial sites around the IInd and IIIrd Mikulčice church now include 950 graves (Fig. 1a, 1b). From these, 928 skeletons or parts of skeletons, which could be marked as the remains of individuals, were available for our evaluation. The remaining bones consisted of grave admixtures.

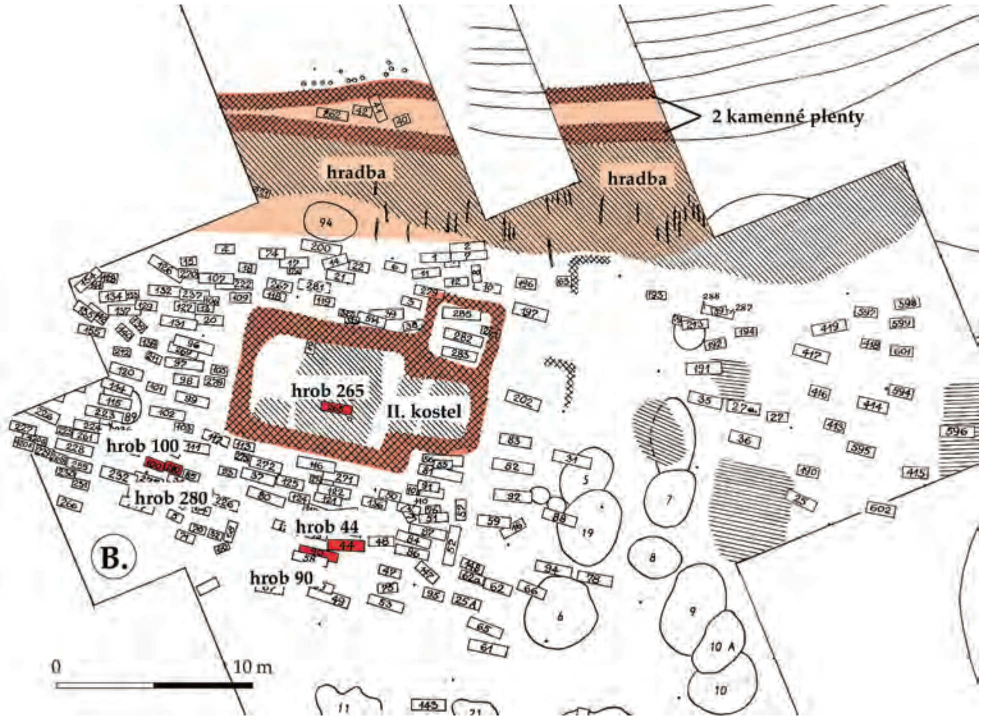


Fig. 1a. Mikulčice-castle. Burial-grounds- in the surrounding of the II[nd] church.

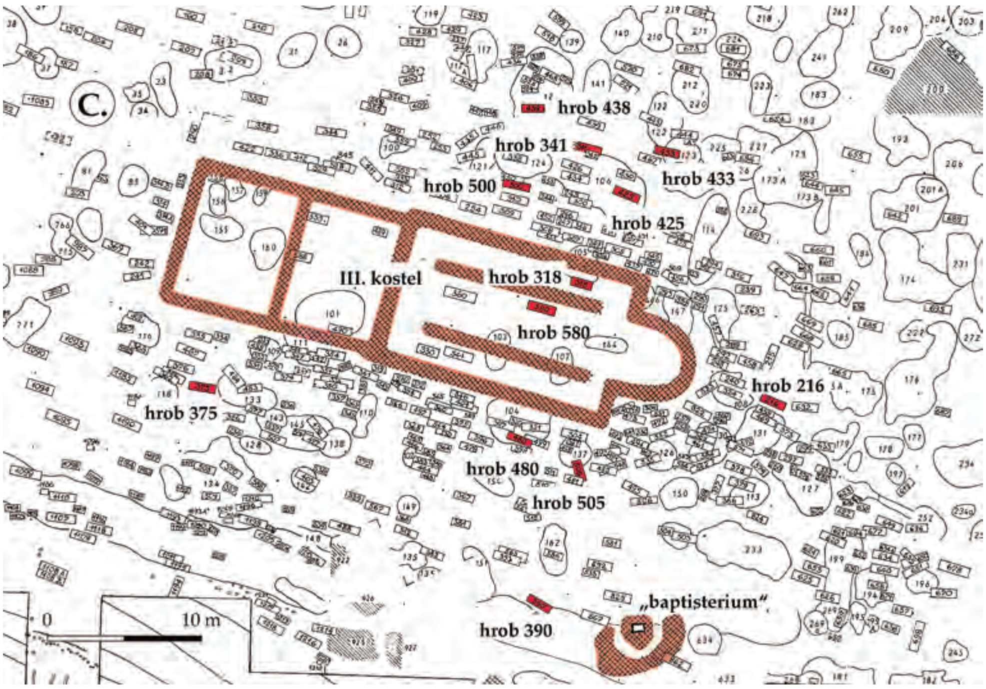


Fig. 1b. Mikulčice-castle. Burial-grounds in the surrounding of the III[rd] church.

2.2 Basic demographic data

A total of 928 individuals originate from both the evaluated burial sites, i.e. from the whole locality of Mikulčice castle. We excluded from our research the skeletons of children, which represent a total of 348 individuals. We evaluated a total of 49 skeletons of juvenile individuals and 531 of adults. In five cases, the material was designated as grave admixture.

Our group of evaluated adults included a total of 217 female, 286 males and 28 individuals of undetermined sex. From the aspect of age, the adult group contained 163 individuals of the adultus age group (Ad. I-II, 20-39 years),

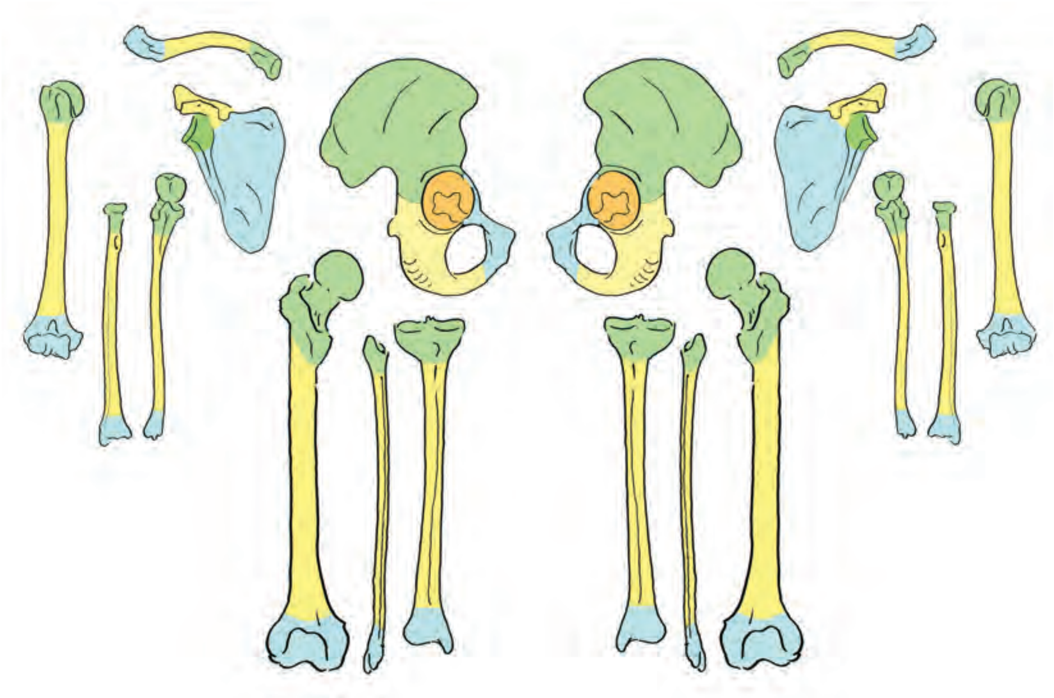


Fig. 2. Definition of evaluated bone segments of locomotory apparatus

302 individuals of the maturus age group (Mat. I-II, 40-59 years) and 22 individuals of the senilis age group (Sen., over 60 years). There were 94 adult females and 67 adult males. The maturus group included 108 females and 188 males, and the senilis group 8 females and 14 males. The sex could not be determined in the remaining individuals in each category (Graph 1).

3. Methods

3.1 Diagnostics of bone fractures

All the bones were evaluated aspectively, and their degree of preservation (or completeness according to the selected division into segments – see below) was recorded, as was the eventual presence of traumatic changes: alterations of the bone axis, irregularities of the bone surface, the presence of pseudo-joints etc. Although post-traumatic changes are quite apparent already on visual inspection, X-rays of all suspected traumatic lesions were made and assessed, in order to verify the presence and to determine the extent of the given lesions (the course of the fracture line, the extent of reparative changes, eventual complications – see Stloukal/Vyhnánek 1976). Photo-documentation was made concurrently.

During the evaluation itself, we based our procedures on publications dedicated to traumatology or orthopaedics, including works deemed historical today (e.g. Hoffa 1896) and on paleopathological literature (e.g. Steinbock 1976; Aufderheide/Rodríguez-Martín 1998; Roberts/Manchester 2007).

3.2 Population evaluation of fractures of the post-cranial skeleton

We approached the issue of evaluating the frequency of traumatic lesions within the selected population not only in relation to the number of individuals involved, but mainly to the state of preservation of individual bones and their sections. In view of the size of the population studied and the degree of preservation of the material, we based ourselves mainly on the method described by Judd (2002), which was devised for the evaluation of fragmented skeletal material. We simplified the method of five segments in view of the degree of preservation of the material studied as

Table 1. The incidence of fractures in the evaluated population, number of bones and segments.
N = number of evaluated cases; M = male, F = female, ? = undetermined, adm = admixture

	F+M+?	F	M	?
n of individuals	531	217	286	28
individuals with fracture	42	8	31	3
% of individuals with fracture	7.91	3.69	10.83	10.71
n of bone segments	14346	5906	8131	309
n of fractures	54	8	43	3
% of segment fracture	0.38	0.14	0.53	0.97
n of realy whole bones	3362	1343	1947	72
n of „whole" bones calculated by extrapolation	459	224	217	18
% of fractures of all whole bones	1.41	0.51	1.99	3.33

follows: we considered the diaphyses of long bones to be a single segment; in the case of the scapula we evaluated independently the cavitas glenoidalis region, acromial and coracoid processes, and the surface of the scapula itself. We divided the pelvis anatomically into the os illii, os ischii and os pubis, with the acetabulum evaluated as an independent unit because of the possibility of indirect trauma (Fig. 2). The demarcation of the epiphyses of long bones corresponded to the older, practical method of squares (Müller et al. 1990).

The division of bones into segments enabled us not only to evaluate truly preserved complete bones, but also to increase the number of individual bones by extrapolating segments preserved independently within the selected groups (non-adults, adult females, adult males and adults of undetermined sex).

Fisher's exact test of the four-field contingency table (Dixon/Massey 1969) at a 5% and 1% level of significance was used to mutually compare the differences in the incidence of trauma in the individual groups evaluated.

4. Results

4.1 Frequency of fractures in the population

The incidence of fractures was evaluated in relation to the individuals affected, the individual bones, as well as the localisation of the traumatic lesions themselves on the bones divided into three independently studied segments, and in the case of the pelvis into four independently studied segments.

From the aspect of fracture incidence, the bones of 49 individuals included in the juvenis group (15-19 years) were evaluated. In this group, 216 individual complete bones as well as incomplete bones were evaluated – the total number of segments evaluated (complete bones and fragments) was 839. No fracture was recorded on the studied bones in the juvenis group.

Adults represented a total of 531 individuals – a total of 3362 complete bones were examined, with the help of segments this number was increased by a further 452 "complete" bones using extrapolation (total of 3814 bones); a total of 14346 individual segments were evaluated. This number is incremented by additional findings designated as admixtures – this involved a total of 21 segments, including six complete bones (total of 14367 segments).

A total of 54 fractures were recorded in the whole group of adult individuals, the number of individuals with a fracture was 42 – individuals with a fracture represented 7.91% of the population. If we add the bones designated as admixtures, the number of fractures uncovered increases to 59. Thus, from the total 3814 evaluated bones (including those calculated by extrapolation), bones with a fracture represent 1.54%. From the total of 14367 evaluated segments, fractures represent 0.41%.

Table 2. The bones, evaluated bone segments and observed fractures of the pectoral girdle and long bones of the upper extremity.

		clavicle						scapula					
		dx			sin			dx			sin		
		sternal	diaphysis	acromial	sternal	diaphysis	acromial	glen	proc	angulus	glen	proc	angulus
F	n of bone segments	109	116	98	108	115	94	115	49	17	115	49	18
	n of fractures	-	-	-	-	1	-	-	-	-	-	-	-
	% of segment fracture	-	-	-	-	0.87	-	-	-	-	-	-	-
	n of realy whole bones		87			82			16			18	
	n of „whole" bones calculated by extrapolation		11			12			1			-	
	% of fractures of all whole bones		-			1.06			-			-	
M	n of bone segments	162	164	143	153	154	132	156	83	35	145	73	28
	n of fractures	-	-	2	-	3	4	1	1	1	2	-	-
	% of segment fracture	-	-	1.4	-	1.95	3.03	0.64	1.2	2.86	1.38	-	-
	n of realy whole bones		137			128			33			27	
	n of „whole" bones calculated by extrapolation		6			4			2			1	
	% of fractures of all whole bones		1.4			5.3			8.75			7.14	
?	n of bone segments	6	6	6	5	6	6	6	3	1	6	1	2
	n of fractures	-	-	-	-	-	1	-	-	-	-	-	-
	n of realy whole bones		6			5			1			1	
	n of „whole" bones calculated by extrapolation		-			-			-			-	
ant	n of bone segments	1	1	1	-	-	-	-	-	-	-	-	-
	n of fractures	-	-	1	-	-	-	-	-	-	-	-	-
	n of realy whole bones		1			-			-			-	
F + M + ? + ant	n of bone segments	278	287	248	266	275	232	277	135	53	266	123	48
	n of fractures	-	-	3	-	4	5	1	1	1	2	-	-
	% of segment fracture	-	-	1.21	-	1.46	2.11	0.36	0.74	1.89	0.75	-	-
	n of realy whole bones		231			215			50			46	
	n of „whole" bones calculated by extrapolation		17			17			3			2	
	% of fractures of all whole bones		1.21			3.88			5.66			4.17	

In the group of females (total of 217 individuals), there were eight fractures in a total of eight individuals. In the population of females, this represents 3.69% individuals with fractures. From the aspect of age, six cases involved females of the maturus category and two cases was recorded in the adultus age category.

humerus						radius						ulna					
dx			sin			dx			sin			dx			sin		
proximal	diaphysis	distal	proximal	diaphysis	distal	proximal	diaphysis	distal	proximal	diaphysis	distal	proximal	diaphysis	distal	proximal	diaphysis	distal
99	151	103	103	154	103	105	122	108	88	114	100	101	113	82	98	107	79
-	-	-	-	-	-	-	-	-	-	1	-	-	3	-	-	-	-
-	-	-	-	-	-	-	-	-	-	0.88	-	-	2,65	-	-	-	-
	75			77			88			76			69			68	
	28			26			17			12			13			11	
	-			-			-			1.14			3.66			-	
136	199	158	134	189	142	143	171	159	136	167	157	154	158	126	148	160	120
1	1	1	2	2	-	-	2	1	-	1	3	-	1	-	-	3	1
0.74	0.5	0.63	1.49	1.06	-	-	1.17	0.68	-	0.6	1.91	-	0.63	-	-	1.88	0.83
	125			114			125			123			113			105	
	11			20			18			13			13			15	
	2.21			2.98			2.09			2.94			0.79			3.33	
6	7	5	5	7	6	5	6	5	5	5	6	5	6	5	4	6	6
-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	1	-
	5			5			5			4			5			4	
	-			-			-			1			-			-	
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	1	-
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-
	-			-			-			-			-			-	
241	357	266	242	350	251	253	299	272	229	286	263	260	277	213	251	274	205
1	1	1	2	2	-	-	2	1	-	3	3	-	4	-	-	5	1
0.41	0.28	0.38	0.82	0.57	-	-	0.67	0.36	-	1.04	1.14	-	1.76	-	-	1.82	0.49
	205			196			218			203			187			177	
	36			46			35			26			26			28	
	1.24			1.65			1.19			2.62			1.88			2.93	

In the group of males (286 individuals), a total of 43 fractures were uncovered in 31 individuals – several cases involved multiple injuries (see below). Males with fractures in this group thus represent 10.83%. From the aspect of the age reached, fractures were recorded in two males from the adultus category, in 28 males from the maturus category and in two individuals from the senilis group.

Table 3. The bones, evaluated bone fragments and observed fractures of the pelvic bone and long bones of the lower extremity.

		pelvic bone							
		dx				sin			
		acetabulum	ilium	pubis	ischium	acetabulum	ilium	pubis	ilium
F	n of bzone segments	123	98	70	72	123	96	71	77
	n of fractures	-	-	-	-	-	-	-	-
	% of segment fracture	-	-	-	-	-	-	-	-
	n of realy whole bones		56				57		
	n of „whole" bones calculated by extrapolation		14				14		
	% of fractures of all whole bones		-				-		
M	n of bone segments	181	132	120	119	179	125	125	118
	n of fractures	-	-	1	-	-	-	2	-
	% of segment fracture	-	-	0.83	-	-	-	1.6	-
	n of realy whole bones		97				97		
	n of „whole" bones calculated by extrapolation		22				28		
	% of fractures of all whole bones		0.84				1.69		
?	n of bone segments	5	5	5	4	5	6	3	3
	n of fractures	-	-	-	-	-	-	-	-
	n of realy whole bones		4				3		
	n of „whole" bones calculated by extrapolation		-				-		
ant	n of bone segments	-	-	-	-	-	-	1	-
	n of fractures	-	-	-	-	-	-	-	-
	n of realy whole bones		-				-		
F + M + + ? + ant	n of bone segments	309	235	195	195	307	227	200	198
	n of fractures	-	-	1	-	-	-	2	-
	% of segment fracture	-	-	0.51	-	-	-	1	-
	n of realy whole bones		157				157		
	n of „whole" bones calculated by extrapolation		38				43		
	% of fractures of all whole bones		0.51				1.0169		

The difference in the frequency of fractures between males and females – regardless whether we based our calculations on the number of individuals with fractures or on the total number of fractures uncovered – is significant at the 1 % level of significance.

The group of adult individuals with no possibility of determining sex is the smallest – only 28 individuals. In this group, three fractures were recorded in three individuals.

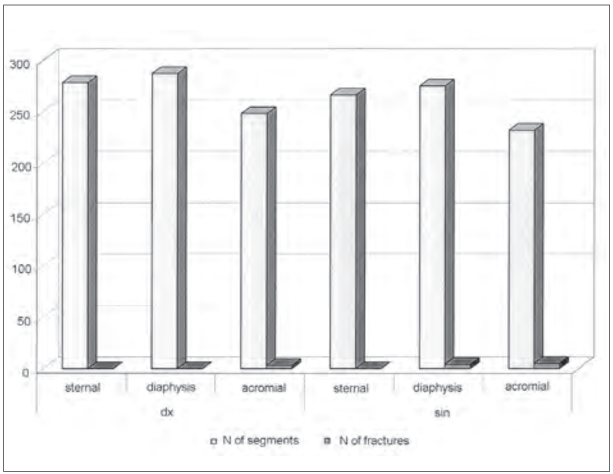
Cases designated as admixtures represent a special group (see Section 5.2). Only eight bones

femur						tibia						fibula					
dx			sin			dx			sin			dx			sin		
proximal	diaphysis	distal	proximal	diaphysis	distal	proximal	diaphysis	distal	proximal	diaphysis	distal	proximal	diaphysis	distal	proximal	diaphysis	distal
141	177	146	142	173	150	131	156	134	125	154	142	48	89	89	52	97	97
-	-	-	1	-	-	-	-	-	1	-	-	-	-	-	1	-	-
-	-	-	0.7	-	-	-	-	-	0.8	-	-	-	-	-	1.92	-	-
	126			130			117			116			39			46	
	15			12			14			9			9			6	
	-			0.7			-			0.8			-			1,92	
188	228	185	192	221	178	158	204	178	157	201	179	54	111	117	55	119	122
-	1	-	-	-	-	-	-	1	-	-	-	-	1	-	1	2	1
-	0.44	-	-	-	-	-	-	0.56	-	-	-	-	0.9	-	1.81	1.68	0.82
	167			166			147			142			52			49	
	18			12			11			15			2			6	
	0.53			-			0.63			-			1.85			7.27	
5	12	7	7	15	6	4	9	10	4	6	8	4	5	6	3	4	4
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	5			5			4			3			4			3	
	-			1			-			1			-			-	
1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	-	-	-
1	-	-	-	-	-	-	1	-	-	-	-	-	1	-	-	-	-
	1			1			1			1			1			-	
335	418	339	342	410	335	294	370	323	287	362	330	107	206	213	110	220	223
1	1	-	1	-	-	-	1	1	1	-	-	-	2	-	2	2	1
0.3	0.24	-	0.29	-	-	-	0.19	0.31	0.35	-	-	-	0.97	-	1.81	0.91	0.45
	299			302			269			262			96			98	
	36			33			18			25			11			12	
	0.6			0.3			0.34			0.35			1.87			4.55	

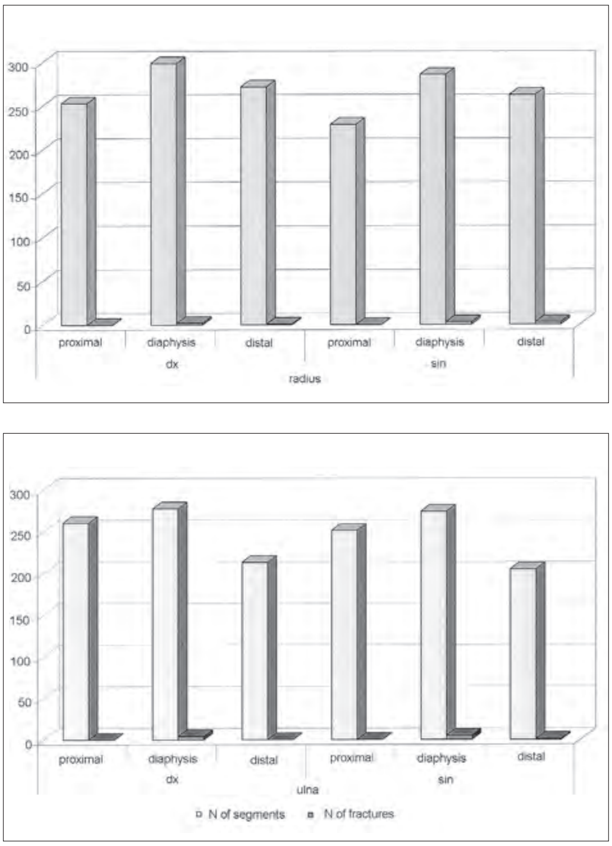
were evaluated, of which six were complete, and fractures were uncovered in five cases.

An overview of the incidence of fractures in the evaluated population, including their relation to the number of segments evaluated is presented in Table 1.

Multiple fractures were noted in several individuals, and in some it is highly probable that they occurred concurrently. In one case, four fractures were discovered on a single skeleton (scapula, humerus, radius, fibula), in another three were found (clavicle, humerus, tibia).



Graph 2. The frequency of clavicle´s fractures in relation to localisation of injury.



Graph 3. The frequency of forearm bones fractures in relation to localisation of injury.

The remaining cases involved fractures of two bones (for details of individual findings see Section 4.3).

4.2 Localisation of injuries

4.2.1 Incidence and frequency of fractures according to the individual evaluated bones

4.2.1.1 Fractures of the pectoral girdle bones and the upper limb´s long bones

Fractures of the clavicle were recorded in the group of females in only one case; in the group of males, they were recorded in a total of nine cases (for the number of bones and segments see Table 2) – the difference between the sexes is not significant. In two cases, the fractures were localised on the right (on the acromial end), eight cases were localised on the left (4 x fracture of the diaphysis, 4 x traumatic changes of the acromial end) – the difference in laterality is also not significant (Graph 2).

Traumatic changes of the scapula were recorded only in males, namely in five cases. A total of three cases involved the region of the glenoid cavity, one case involved the acromial process and another of the margo lateralis. In view of the poor state of preservation, it was possible to evaluate only the differences in numbers in the case of the cavitas glenoidalis, and not in relation to complete bones: three fractures from a total of 301 evaluated cavitas glenoidalis of males and 0 cases in 230 cavitas glenoidalis of females do not represent a statistically significant difference.

Even fractures of the humerus were uncovered only in males, namely in seven cases. Three fractures were recorded in the region of the proximal epiphysis, three fractures involved the diaphysis and one trauma was noted in the region of distal epiphysis. The difference in laterality, 3:4, is not statistically significant. The difference in the incidence of fractures in males compared to the unaffected females (for the number of bones and fragments see Table 2) is significant at the 5% level of significance.

Fractures of the forearm were uncovered in both sexes. Fractures of the radius in males were recorded in seven cases – three on the right, four on the left. On the right, two were located in the region of the diaphysis and one in the distal epiphysis; on the left, one was located in the region of the diaphysis and three in the distal epiphysis. In females, only a single fracture of the radius – on the left, in the region of the diaphysis – was recorded. The differences in laterality are not significant. The inter-sexual difference is also not significant. Fractures of the ulna were recorded in females in three cases (on the right), and in males in five cases (one on the right, four on the left). Neither the difference between the right and left side, nor the difference between the sexes are statistically significant (Graph 3; for number of bones and segments see table 2).

4.2.1.2 Fractures of the pelvis and the lower limb´s long bones

Fractures of the pelvic bones were discovered only in males, and from the aspect of localisation only in the region of the pubic bone rami. These findings involved two cases of fractures, in one case the lesion was bilateral. Although no fracture of the pelvic area was discovered in females, the difference is not significant (for number of bones and evaluated regions see Table 3).

Fractures of the femur were discovered in both males and females – only one case in each sex: in the female in the region of the neck on the left, and in the male in the region of the diaphysis. A third case, from a pathological aspect the most interesting, was discovered in the material designated as grave admixture.

Similarly, the incidence of tibia fractures was rare – similarly as in the case of fractures of the femur, one case in a male (distal epiphysis) and one case in a female (proximal epiphysis). A third case was also involved (fracture of the diaphysis), discovered in material designated as grace admixture. Fracture of the fibula was recorded in one female in the region of the proximal epiphysis, and in males in a total of 5 cases on the left located on the diaphysis, on the right one located on the proximal end, two fracture of the diaphysis and one fracture in the region of the malleolus (for number of bones and segments see Table 3).

4.2.2 The most frequent localisation of fractures

If we compare the frequency of fractures of individual bones (regardless of laterality), the overview above shows that the most frequently represented fractures in the population are those of the clavicle – a total of 12 cases (a total of 480 complete bones were evaluated, including the undetermined individuals and admixtures and including bones calculated by extrapolation). The second most frequent localisation is the forearm – a total of nine fractures of the radius were recorded (of a total 483 complete bones), nine fractures of the ulna (of a total of 418 complete bones). Next in frequency are fractures of the humerus with 7 fractures uncovered (483 complete bones).

The rate of the most frequently uncovered fracture of the clavicle is statistically significantly higher compared to other bones only in the case of the least often affected femur (at the 1% level of significance) and tibia (at the 5% level of significance). The higher frequency of fractures of the clavicle in the evaluated population, though, is not statistically significant even in relation to the frequency of the relatively rare fractures of the pelvic region. The second most frequent localisation of fractures – ulna – is statistically significantly higher compared to femur and tibia (at the 5% level of significance), frequency of fractures of radius is statistically significantly higher in comparison with femur (at the 5% level of significance).

The incidence of fractures of the pectoral girdle and long bones of the upper extremity is significantly higher than the incidence of fractures of the pelvis and the long bones of the lower extremity, at the 1% level of significance. A statistically significant difference remains even if the scapula with low preservation of the area of the angle is not included in the overall comparison in the case of the upper extremity. This significantly decreases the number of complete bones, thus limiting the evaluation.

4.3 Overview of findings of post-traumatic lesions of the locomotor apparatus

Grave No 29 – adult individual, undetermined age and sex
healed fracture of the distal half of the left ulna

(complete preservation of both bones of the forearm (Fig. 3)

Grave No 39 – male, maturus II (50-60 years)
healed fracture of the clavicle body on the left (distal end not preserved) (Fig. 4)

Grave No 56 – female, maturus I (40-50 years)
healed fracture of the lateral half of the diaphysis of the left clavicle (clavicles bilaterally preserved, scapula partially evaluable on the left-without traumatic changes)

Grave No 94 adm. – adult individual, undetermined age and sex; two individuals (admixture)
post-traumatic changes of the acromial end of the clavicle on the right, fusion of the clavicle with the processus acromialis cannot be ruled out, concurrent healed fracture of a rib on the right (Fig. 5)

Grave No 104 – male, maturus I (40-50 years)
healed fracture of the distal end of the left radius (complete preservation of both bones of the forearm)

Grave No 114 – female, maturus I (40-50 years)
healed medio-cervical fracture of the femoral neck on the left (femurs bilaterally preserved, pelvis quite incomplete- acetabula cannot be evaluated) (Fig. 6, 7)

Grave No 126 – female, maturus II (50-60 years)
depressive fracture of the lateral articular surface of the tibia condyle on the left

Grave No 180 – male, maturus I (40-50 years)
healed fracture of the distal end of the diaphysis of the right radius (the proximal epiphysis of the bone not preserved, only the diaphysis of the ulna available for comparison, the contralateral forearm completely missing)

Grave No 198 – male, maturus I (40-50 years)
healed fracture of proximal end of diaphysis od the fibula left with imflammatory complications (fibula right and tibia of both sides ale well preserved) (Fig. 8)

Grave No 202 adm. – grave admixture; adult individual, undetermined age and sex,
healed fracture of the diaphysis of the tibia and concurrently of the diaphysis of the fibula on the right

Grave No 207 adm. – admixture; adult individual, undetermined age and sex
healed fracture of the proximal half of the diaphysis of the left ulna (Fig. 9)

Grave No 209 – male, maturus II (50-60 years)
healed fracture of the neck of the humerus on the left with subsequent secondary arthrosis and post-traumatic changes to the cavitas glenoidalis of the left scapula with signs of luxation; healed fracture of the distal epiphysis of the radius; healed fracture of the fibular malleolus on the left (skeleton well preserved, with the exception of bilateral damage to the fibula the long bones of the extremities are complete; moreover prior fracture of the sternal end of a rib)

Grave No 223 – male, maturus II (50-60 years)
healed fracture of the proximal third of diaphysis of the left fibula (from this bone is preserved only its diaphysis; right-side fibula ant tibia are not present)

Grave No 237 – female, adultus II (30-40 years)
healed fracture of the diaphysis of the right ulna (from this bone is missing the distal epiphysis, the left ulna is missing the proximal epiphysis, radius of the right and left side is missing the distal epiphysis)

Grave No 252 adm. – grave admixture; adult individual, undetermined age and sex
the medio-cervical fracture of the femoral neck healed by pseudo-articulation. (The grave admixture is represented only by this bone) (Fig. 10-12, cf. Fig. 13)

Grave No 254 – female, maturus I (40-50 years)
healed fracture of the proximal half of the diaphysis of the left radius (the left ulna and bones of the contralateral forearm are complete)

Grave No 264 – female, maturus II (50-60 years)
healed fracture of the distal half of the diaphysis of the right ulna (completely preserved bones of the forearm bilaterally, with the exception of the distal epiphysis of the fractured ulna on the right) (Fig. 14)

Grave No 268 – male, maturus I (40-50 years)
healed fracture of the pubic bone on the left (pelvis complete) (Fig. 15)

Grave No 269 – male, senilis (> 60 years)
healed fracture of the acromial end of the left clavicle, concurrently with post-inflammatory changes (the acromial end of the clavicle on the right not preserved, on the left preserved without damage to the processus acromialis or coracoideus) (Fig. 16)

Grave No 274 – undetermined sex, maturus (40-60 years)
healed old fracture of the distal section of the left radius (the bone is missing the proximal epiphysis, the left ulna is complete, both bones of the forearm on the contralateral side are missing the proximal epiphyses)

Grave No 276 – male, maturus II (50-60 years)
healed fracture of the diaphysis of the left clavicle, healed fracture of distal third of the diaphysis

of the left ulna (the right clavicle undamaged, the scapula on the left as well as in the region of the processus coracoideus and acromion without pathology, the right ulna is presented only by diaphysis, right radius is well preserved, the left radius is missing proximal diaphysis) (Fig. 17, 18)

Grave No 278 – male, senilis (>60 years)
prior fracture of the middle section of the diaphysis of the left fibula (only this diaphysis of the fibula on the left preserved from the among the shin bones)

Grave No 306 – male, maturus II (50-60 years)
prior fracture of the acromial end of the left clavicle; post-traumatic changes of the medial condyle of the right humerus, which is missing; callus on the medial side of the distal epiphysis of the right tibia; prior bilateral luxation of the sterno-clavicular joint (of the long bones of the extremities, only the head of the humerus on the right is missing; of the right radius, only the proximal epiphysis is preserved) (Fig. 19-22)

Grave No 317 – male, adultus I (20-30 years)
healed fracture of the distal half of the diaphysis of the left radius (both bones of the forearm preserved bilaterally) (Fig. 23)

Grave No 359 – male, maturus (50-60 years)
healed fracture of the diaphysis of the right radius with dislocation peripherally (the long bones of the extremities completely preserved; myositis ossificans on the linea aspera of the right femur) (Fig. 24-25)

Grave No 362 – male, maturus I (40-50 years)
healed fracture of the proximal third of the diaphysis of the left humerus (the remaining bones of the upper extremities preserved, without any traumatic changes) (Fig. 26-27)

Grave No 401 – male, maturus II (50-60 years)
healed fracture of the diaphysis of the left clavicle (the clavicles preserved bilaterally; only the region of the cavitas glenoidalis of the scapulae evaluable) (Fig. 28)

Grave No 423 – male, maturus I (40-50 years)
healed fracture of the lower rami of the pubic bone bilaterally, these changes are more apparent on the left (on the right, the os ischii is damaged and on the left, the os ilium is damaged) (Fig. 29)

Grave No 450 – male, maturus I (40-50 years)
post-traumatic changes of the acromion of the right scapula (the scapulas and clavicles preserved undamaged bilaterally)

Grave No 476 – male, maturus I (40-50 years)
healed fracture of the cavitas glenoidalis region and below the spina scapulae on the right with the formation of a new articular surface ventrally; fracture of the neck and diaphysis of the right humerus with dislocation and a large callus; significant secondary arthritic changes of the humeral head (the long bones of the left upper extremity are missing, only the distal epiphysis of the ulna is missing on the right) (Fig. 30-32)

Grave No 479 – male, maturus II (50-60 years)
fracture of the distal third of the diaphysis of the left ulna, healed with a pseudo-articulation (both bones of the forearm preserved bilaterally) (Fig. 33)

Grave No 520/II – adult individual, undeterminable age and sex
healed fracture of the acromial end of the left clavicle (clavicles preserved bilaterally, scapula missing on the left)

Grave No 604 – male, maturus I (40-50 years)
healed spiral fracture of the middle section of the diaphysis of the left humerus (the bone is missing the proximal epiphysis and the proximal end of the diaphysis); post-traumatic changes on the anterior cavitas glenoidalis of the left scapula (the bones of the left forearm preserved, the right humerus and ulna preserved) (Fig. 34, 35)

Grave No 617 – male, maturus I (40-50 years)
post-traumatic changes of the left shoulder joint with fusion of the humeral head and the cavitas glenoidalis (the scapula is not well-preserved, the humerus is missing the diaphysis) – in view of the poor state of preservation, the presence of an eventual pseudo-articulation in the region of the humeral neck of cannot be assessed (Fig. 36, cf. Fig. 37)

Grave No 634 – male, maturus II (50-60 years)
healed fracture of the acromial end of the right clavicle (both clavicles complete, only the cavitas glenoidalis evaluable on the scapulas) (Fig. 38)

Grave No 640 – male, maturus II (50-60 years)
healed fracture of the proximal end of the left fibula (all the long bones of the lower extremities preserved bilaterally) (Fig. 39)

Grave No 641 – female, adultus I (20-30 years)
healed fracture of the distal third of the diaphysis of the right ulna (only this diaphysis preserved from the forearm)

Grave No 657 – male, maturus II (50-60 years)
healed fracture of the distal end of the right clavicle; healed fracture of the diaphysis of the left ulna (the left radius not preserved, both bones of the right forearm preserved)

Grave No 684 – male, maturus I (40-50 years)
healed fracture of the margo lateralis of the right scapula (association with another possible injury cannot be assessed – only this fragment of the scapula and the diaphysis of the left ulna have been preserved from the bones of the upper extremity; healed fracture of a rib on the left) (Fig. 40)

Grave No 705 – male, maturus I (40-50 years)
healed fracture of the distal half of the body of the right ulna (only the proximal epiphysis of the radius preserved, the bones of the left forearm complete)

Grave No 707 – male, maturus I (40-50 years)
healed fracture of the acromial end of the left clavicle with exostosis (possible communication with the dorsal part of the processus coracoideus of the left scapula – this was not preserved though) (Fig. 41)

Grave No 717 – male, adultus II (30-40 years)
post-traumatic changes of the acromial end of the left clavicle with significant exostosis below and parallel to the processus acromialis of the bone (scapula not preserved, the right scapula and clavicle not preserved either)

Grave No 769 – male, maturus I (40-50 years)
healed fracture of the distal epiphysis of the right radius (ulna damaged, only the proximal epiphysis preserved, bones of the left forearm complete)

Grave No 1100 – female, maturus (40-60 years)
healed fracture of the head of the left fibula (shin bones complete, only the head of the right fibula is missing)

Grave No 1195 – male, maturus I (40-50 years)
healed fracture of the diaphysis of the right femur with significant dislocation longitudinally with contraction and *ad latus et ad axim* (the pelvis bilaterally and the left femur undamaged, tibia preserved, fibulas bilaterally preserved without heads (Fig. 42, 43))

Grave No 1213 – male, maturus (40-60 years)
healed fracture of the distal end of the left radius and ulna (complete bones of the forearm bilaterally preserved; moreover presence of significant exostosis on the medial side of the distal third of the right femur and inflammatory changes of the periosteum of the distal end of the tibia bilaterally) (Fig. 44)

The sex of individuals was determined by M. Stloukal (1967). Brůžek/Velemínský (2006) and Likovský/Velemínský/Zikán this book (pp. 223-235), age was estimated by M. Stloukal (1967).

5. Discussion

5.1 Population evaluation of the incidence of traumatic changes

5.1.1 Detected frequency of traumatic changes

The population evaluation of the incidence of traumatic changes on the skeleton has been the subject of many studies. These works – with a few exceptions – showed a very low percentage of injuries to individual bones. In contrast to our study, these works mostly did not include in their evaluation the clavicle, scapula and pelvis (for an overview see Manchester/Roberts 2007), despite the fact that older publications had already pointed out an increased incidence of fractures of the clavicle (in the case of Mikulčice Stloukal/Vyhnánek 1976).

As we lack the possibility of comparing our group with another population of the early Middle Ages, the studies dedicated to the prevalence of fractures in the British population of the High Middle Ages are "closest" to our group. With the exception of findings from the leprosarium in Chichester, where involvement of the bones with the lepromatous form of leprosy is presumed to be a factor contributing to the higher incidence of fractures (Judd/Roberts 1998), and with the exception of the conclusions made in older works mapping out fractures on a very small number of bones from the St. Nicolas Shambles cemetery in London (White 1988), the frequency of affected individual bones is very low – fractures of the radius have most frequently reported, although the frequency of this fracture in individual populations ranges from 0.5 to 1.0% (Stroud/Kemp 1993, Wiggins/Boylston/Roberts 1993, Grauer/ Roberts 1996; Cardy 1997).

Despite the fact that the aforementioned studies did not focus on the frequency of fractures of the clavicle, scapula and pelvis, fractures of the clavicle are usually considered to be the most frequent in archaeological bone groups. Fractures of the clavicle were more frequently observed in the male population, and their higher incidence on the left was noted at the same time (Stloukal/Vyhnánek 1976; Vyhnánek 1999)

– our observations also correspond to this, but the difference in laterality is not statistically significant.

Another type of injury considered to be the most frequent is the fracture of the diaphysis of the radius and/or ulna, which may occur in self-defence. In our group, the frequency of fractures of the ulna or radius is not significantly higher than that of fractures of other bones. The prevalence of fractures of the radius – 1.87% of all evaluated bones – is nonetheless slightly higher than that determined for the studied British bone groups of the High Middle Ages (see above). Also higher, is the prevalence of fractures of the ulna (2.39% of all evaluated bones) and, surprisingly, the incidence of fractures of the humerus – 1.45%.

It is presumed that the incidence of trauma is affected by the lifestyle and the socio-economic standing of the given population and individuals. The sites evaluated in the area in the area of the Mikulčice castle are considered to be the burial sites of the elite. The grave accessories have also given rise to the assumption that warriors were buried at these sites (e.g. Poulík 1975). The uncovered traumatic changes, though, take the form of so-called accidental injuries (Vyhnánek 1999). Although some of the uncovered injuries could have been caused deliberately (e.g. the fracture of the diaphysis of the humerus due to a massive strike etc.), most of these fractures can be explained by the natural conditions of the locality – this was surrounded by many branches of the Morava river, which in the winter undoubtedly froze over, which certainly represented a higher risk of falls and associated accidental injuries.

5.1.2 State of preservation and method of evaluation

The method of evaluation that we used is a certain modification of the so-called method of five segments (Judd 2002), devised for the evaluation of fragmented bones. For practical reasons, though, it does not divide the diaphysis into a proximal, medial and distal section. The demarcation of the segments roughly corresponds to the system of squares (Müller at al. 1990) applying the rules for the ulna and fibula in accordance with Judd (2002), as it has been shown that for the evaluation of long bones – to increase the total number of complete bones by the extrapolation of individual segments of incomplete bones – the limiting factor is not the preservation and completeness of the diaphysis, but that of the epiphysis.

In our group, it was possible to increase the number of individual long bones by tens using extrapolation. Of the long bones, the least preserved was the fibula, where the preservation of the proximal epiphysis (or the area of the head and neck) was nearly one half compared to the preservation of the diaphysis and the area of the malleolus. The greatest pitfall of population evaluation is presented by the scapula, where most frequently only the area of the lateral angle of the cavitas glenoidalis is preserved. The preservation of the acromial and coracoid processes is only half of that and the preservation of the angle of the scapula and margo lateralis is only one fifth. Despite these restrictions, traumatic lesions were uncovered in both the area of margo lateralis and that of the processus acromials – this is why we believe it would be a mistake to exclude the evaluation of this bone, or to restrict such evaluation only to the lateral angle, whose preservation approaches that of the other studied bones.

5.2 Individual cases

The long period of time that elapsed between the removal of the material and its initial evaluation as to health status, including fractures, is one of the reasons why the fractures that we discovered do not correspond completely to the published list (Stloukal/Vyhnánek 1976).

In some cases, one of the problematic issues was the classification of uncovered pathological lesions as "fractures", although their traumatic origin was highly probable. This, for example, applies to the distinctive exostosis on the inferior side of the acromial end of the clavicle from grave No 693: although, morphologically, it resembles the findings in graves No 707 or 717, we were unable to prove unequivocally that this was a true fracture of the bone, not even using radiological examinations. In contrast, the shape of the left clavicle of the individual from grave No 276 seemed to point at changes in shape due to bone asymmetry without the presence of a distinctive callus, yet the X-ray uncovered a fracture line.

As to the individual findings of fractures, in a number of cases we found ourselves in a difficult situation, regarding how to classify the findings. This mainly relates to sections of the skeleton or individual bones that were designated as admixture. In graves No 94 or 202, a section of the skeleton of another (prior?) buried individual was designated as an admixture – in such situations we evaluated the "admixture" as an independent individual.

Another „admixture" involves a group of 8 bones from a total of five graves, of which six are complete. Fractures were uncovered in five cases, other pathologies were found on the remaining bones, for example, advanced degenerative changes. As the studied material mainly originated from the first phase of archaeological research that was conducted in the years 1954-1963 (Poláček 2000) and it was no longer possible to consult the situation of the find with the author of the research (Josef Poulík 1910-1998), the question remains as to how these bones were selected – whether these bones are true grave admixtures, or whether this is a case of directed selection of morphologically altered bones from grave backfills either during removal of the skeletal remains or during laboratory or scientific processing. For example, grave 252 contains as the primary subject of burial a very badly preserved skeleton of a male (of the locomotor apparatus only the diaphyses of the humerus, femurs and tibias are preserved), and as the admixture, in contrast, a very well preserved independent femur with a traumatically separated head, whereby this fracture has healed in the form of a pseudo-articulation. In the original publication (Stloukal/Vyhnánek 1976), this bone is assigned to the primary subject of the burial – it differs, though, from the other bones. Moreover, as has been said above, both femurs of the original subject of burial are preserved, even if only in the form of the diaphyses. As this is a case of a relatively rare complication of the healing process of fractures of the femoral neck, we included this finding in the overview – albeit only as an "admixture".

Another, less usual type of fracture comes from grave No 617. The preservation of the skeleton of the male of maturus I age is unfortunately very bad – post-traumatic changes of the left shoulder joint are present, with adhesion of the head, most probably the detached head of the humerus at the level of the neck, to the cavitas glenoidalis. In view of the poor state of preservation, we cannot assess the eventual pseudo-joint in the area of the neck of the humerus. Nonetheless, analogues described in clinical literature point to this possibility (Hoffa 1896).

As noted above, most of the findings of fractures can be explained as accidental injuries. In the case of the fractures of the diaphysis of the humerus from graves No 362 and especially No 476, we could speculate that these injuries could have also been caused by a forceful strike to the region of the arm. Isolated fractures of the ulna, including the fracture healed with a pseudo-joint from grave No 479, could have developed in self-defence.

6. Summary

The goal of our study was to verify the frequency of injuries to the bones of the locomotor apparatus in a population group buried on the territory of the castle of the Great Moravian settlement agglomeration at Mikulčice. We purposely chose a burial site, where it is presumed that the elite members of society, including warriors, are buried. We thus focused on burial sites next to the IInd and IIIrd church on the Mikulčice castle, and we based our work on the conclusions of M. Stloukal (1963, 1967) in addition to the sections of the necropolis researched later on (Poláček/Marek 2005).

The method of evaluation is based on that of Judd (2002), which was devised for the evaluation

of fragmented skeletal material. We simplified the method of five segments: we took the diaphyses of long bones to be a single segment, we also evaluated the bones of the pectoral girdle of the upper extremities and the pelvis. It has been shown that for the evaluation of long bones (and for increasing their total number by the extrapolation of segments of incomplete bones), the limiting factor is not the state of preservation of the diaphyses, but of the region of the epiphyses. The individual segments of bone are clearly defined. This significantly restricts the eventual differences in the manner of evaluation.

From the aspect of the incidence of fractures, the bones of 49 individuals classified in the juvenis group (15-19 years) were evaluated. In this group, no fracture was recorded on the studied bones. Adults represented a total of 531 individuals – a total of 3362 complete bones were examined, with the help of segments this number was increased by a further 452 "complete" bones using extrapolation (total of 3814 bones); a total of 14346 individual segments were evaluated. This number is incremented by additional findings designated as admixtures. In the whole group, a total of 59 fractures was recorded.

There were 42 individuals with fractures – individuals with fractures represented 7.91% of the population. In the group of females (total of 217 individuals), there were 8 fractures recorded – this represented 3.69% of individuals in the population of females. In the group of males (286 individuals), a total of 31 individuals with a total of 43 fractures were uncovered – in several cases multiple injuries were involved. Males with a fracture in this group represented 10.83%. The difference in the frequency of fractures between males and females was significant at the 1% level of significance. The group of adult individuals in whom sex could not be determined represented 28 individuals. In this group, three fractures were recorded in three individuals. Findings designated as admixture represented a group of eight bones – fractures were uncovered in five cases.

If we compare the frequency of fractures of individual bones (regardless of laterality), fractures of the clavicle were most frequent in the group studied – a total of 12 cases. The second most frequent localisation was the forearm. The frequency of fractures of the clavicle was statistically significantly higher compared to the other bones only in the case of the least affected femur (at the 1% level of significance) and tibia (at the 5% level of significance). The prevalence of fractures of the radius was slightly higher than that described in studies focusing on British skeletal groups from the High Middle Ages. Also higher, was the prevalence of fractures of the ulna and humerus. The incidence of fractures of the pectoral girdle and long bones of the upper extremities was significantly higher than that of fractures of the pelvis and long bones of the lower extremities, namely at the 1% level of significance.

The uncovered traumatic changes have, in most cases, the characteristics of so-called accidental pelvic trauma, although it cannot be ruled out that some of the fractures may have been caused deliberately. The overall higher frequency of fractures may be explained, for example, by the natural conditions of the locality – this was surrounded by multiple branches of the Morava river that undoubtedly froze over in the winter, which certainly led to a higher risk of falls and associated accidental injuries.

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Legends for following pictures

Fig. 3. Grave No 29. Healed fracture of the distal half left ulnar diaphysis.

Fig. 4. Grave No 39. Healed fracture of the left clavicle´s diaphysis.

Fig. 5. Grave No 94. Post-traumatic changes of the right clavicle´s acromial end.

Fig. 6. Grave No 114. Healed medio-cervical fracture of the left femoral neck.

Fig. 7. Grave No 114. Healed medio-cervical fracture of the femoral neck - X-ray picture.

Fig. 8. Grave No 198. Healed fracture of diaphyseal proximal quarter of the left fibula with imflammatory changes.

Fig. 9. Grave No 207, admixture. Healed fracture of the proximal half of the left ulnar diaphysis.

Fig. 10. Grave No 252, admixture. The medio-cervical fracture of the femoral neck healed by the pseudo-articulation.

Fig. 11. Grave No 252, admixture. Postttraumatic changes of proximal end of femur - X-ray picture.

Fig. 12. Grave No 252, admixture. X-ray picture of traumatic isolated femoral head.

Fig. 13. The medio-cervical fracture of the femoral neck healed by the pseudo-articulation exemplified in clinical literature (taken from HOFFA 1996).

Fig. 14. Grave No 264. Healed fracture of the distal half of the right ulnar diaphysis.

Fig. 15. Grave No 268. Changes of the symphysis caused by fracture of the left pubic bone.

Fig. 16. Grave No 269. Healed fracture of the acromial end of the left clavicle.

Fig. 17. Grave No 276. Healed fracture of the diaphysis of the left clavicle with comparison of the right clavicle.

Fig. 18. Grave No 276. Healed fracture of the diaphysis of the left clavicle - X-ray picture.

Fig. 19. Grave No 306. Post-traumatic changes of the acromial end of the left clavicle.

Fig. 20. Grave No 306. Post-traumatic changes of the medial condyle of the right humerus.

Fig. 21. Grave No 306. Distal part of the right humerus with post-traumatic changes of the medial condyle.

Fig. 22. Grave No 306. Distal part of the right humerus with post-traumatic changes of the medial condyle – X-ray picture.

Fig. 23. Healed fracture of the distal half of the diaphysis of the left radius.

Fig. 24. Grave No 359. Healed, dislocated fracture of the diaphysis of the right radius.

Fig. 25. Grave No 359. Healed, dislocated fracture of the diaphysis of the right radius – X-ray picture.

Fig. 26. Grave No 362. Healed fracture of the proximal third of the diaphysis of the left humerus.

Fig. 27. Grave No 362. Healed fracture of the proximal third of the diaphysis of the left humerus – X-ray picture.

Fig. 28. Grave No 401. Healed fracture of the diaphysis of the left clavicle, comparison with the right bone.

Fig. 29. Grave No 423. Healed, bilateral fracture of the lower rami of the pubic bone – X-ray picture.

Fig. 30. Grave No 476. Healed fracture of the right humeral diaphysis with dislocation and a large callus.

Fig. 31. Grave No 476. Neck of the right humerus with secondary arthritic changes of the humeral head.

Fig. 32. Grave No 476. Healed fracture of the cavitas glenoidalis region and below the spina scapulae on the right.

Fig. 33.Grave No 479. Fracture of the diaphyseal distal third of the left ulna, healed with the pseudo-articulation.

Fig. 34. Grave No 604. Post-traumatic changes on the glenoid cavity of the left scapula.

Fig. 35. Grave No 604. Healed spiral fracture of the diaphyseal middle section of the left humerus.

Fig. 36. Grave No 617. Post-traumatic changes of the left shoulder joint with fusion of the humeral head and the glenoid cavity.

Fig. 37. Post-traumatic fusion of the humeral head and the glenoid cavity documented in clinical literature (taken from Hoffa 1996).

Fig. 38. Grave No 634. Healed fracture of the acromial end of the right clavicle, the comparison with the left clavicle.

Fig. 39. Grave No 640. Healed fracture of the proximal end of the left fibula.

Fig. 40. Grave No 684. Healed fracture of the lateral margin of the right scapula – X-ray picture.

Fig. 41. Grave No 707. Healed fracture of the acromial end of the left clavicle with exostosis, the comparison with the left side.

Fig. 42. Grave No 1195. Healed, dislocated fracture of the right femoral diaphysis, the comparison with the left side.

Fig. 43. Grave No 1195. Healed, dislocated fracture of the diaphysis of right femur, posterior wiev.

Fig. 44. Grave No 1213. Healed fracture of the distal end of the left radius and ulna.


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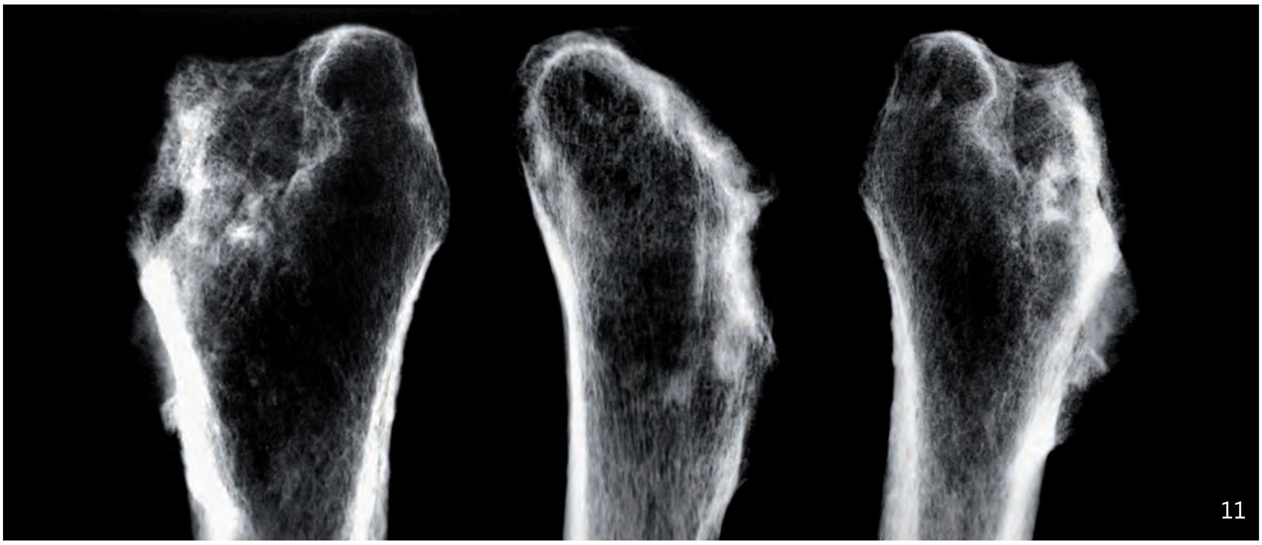
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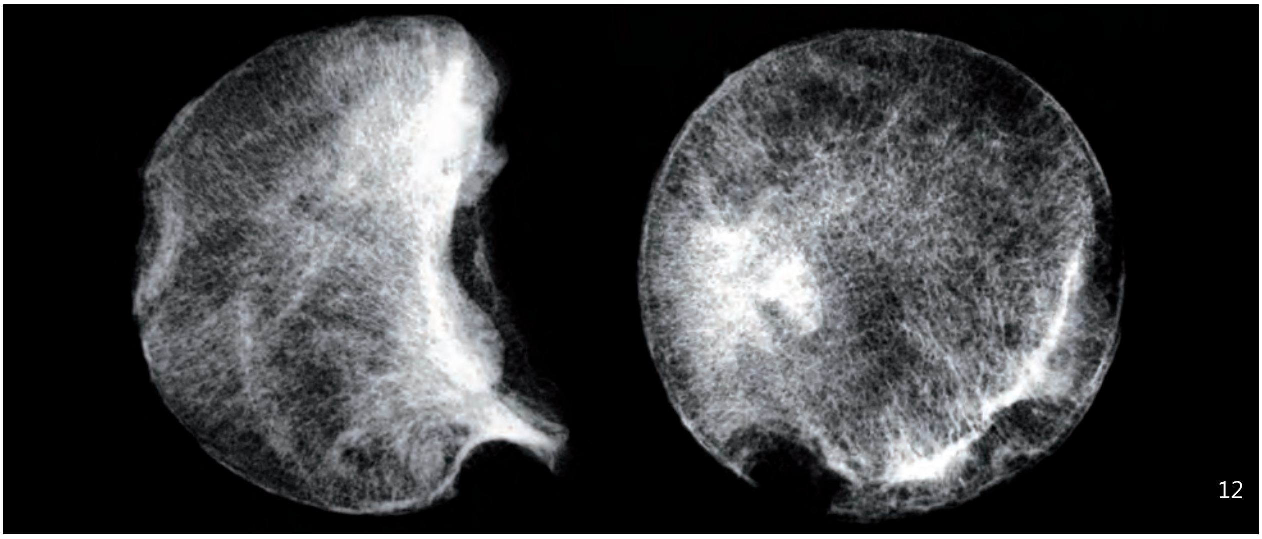
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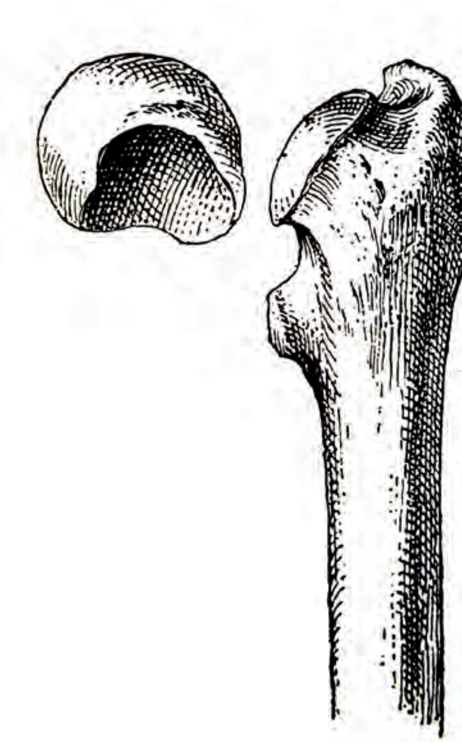
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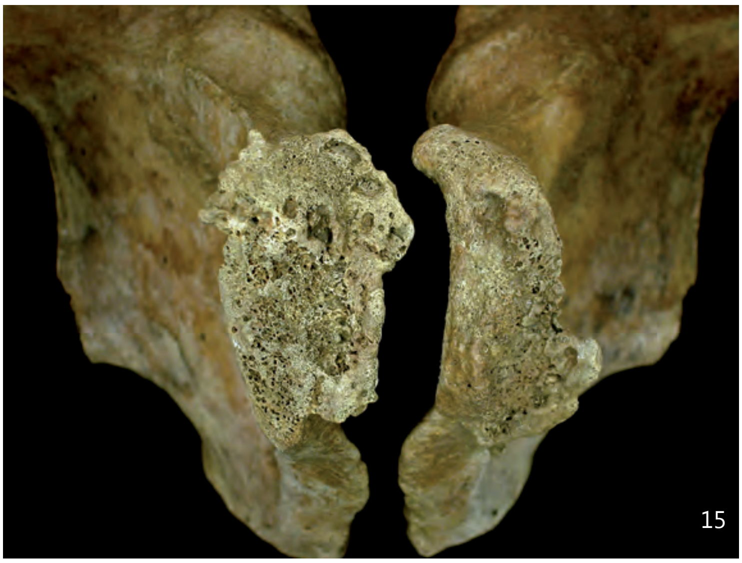
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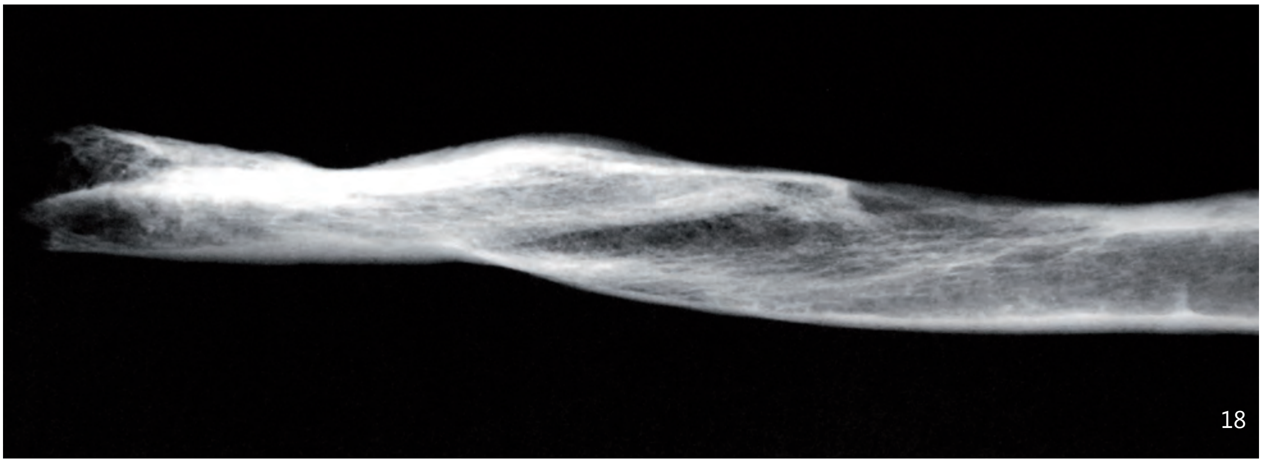
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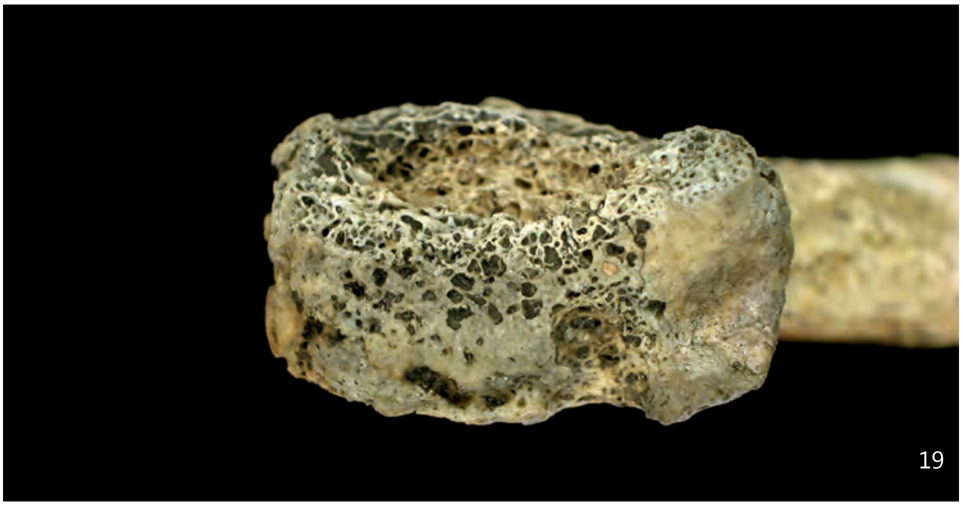
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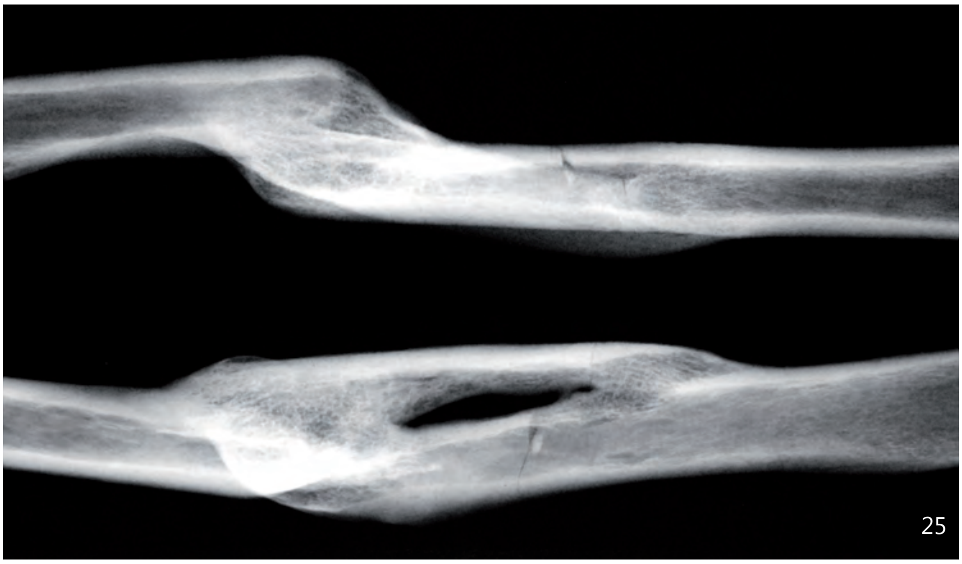
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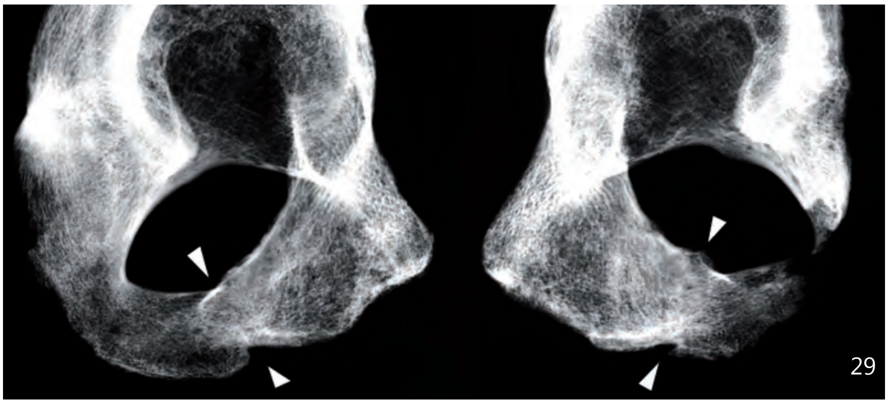

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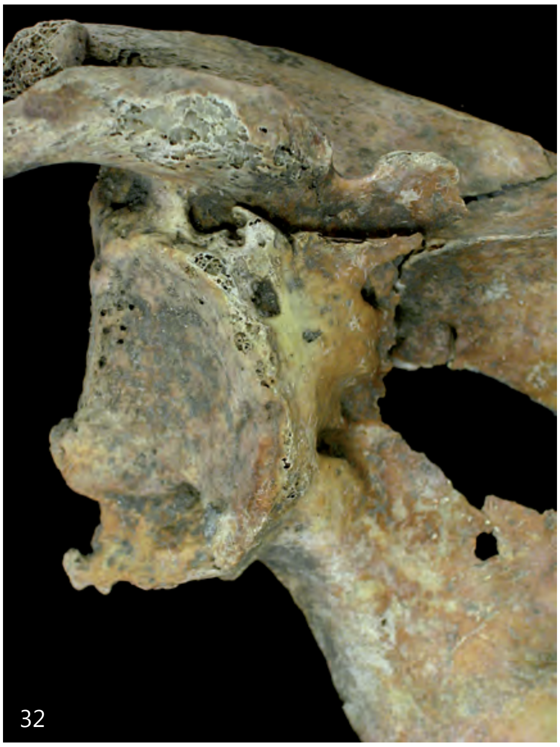

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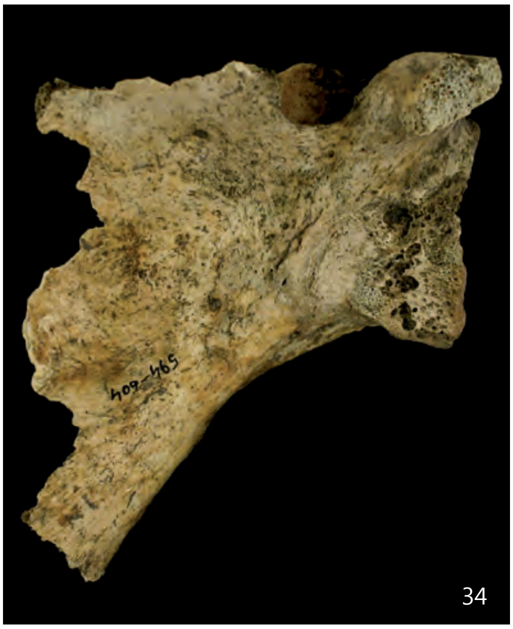

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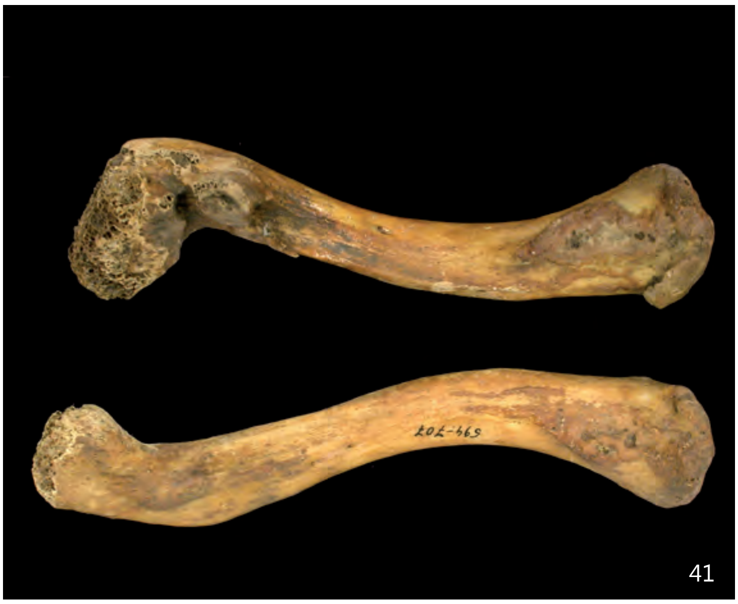
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Biological Diversity of Non-metric Traits in the Great Moravian Population – the Comparison of the Mikulčice Power Centre and its Hinterland

Petr Velemínský[1]– Miluše Dobisíková[1]– Petra Stránská[3]– Jana Velemínská[2]

This study compares different socio-economic groups – Mikulčice castle, the sub-castle area (Kostelisko) and hinterland (Josefov) – on the basis of the variability of non-metric morphological traits. The primary goal was to determine the frequency of around 150 non-metric traits in the largest settlement agglomeration located in Kostelisko (425 graves), and to verify the relationship with sex, or the potential laterality differences in the case of bilateral traits. Then, based on the variability of non-metric traits, we compared individuals buried in the Mikulčice sub-castle with individuals buried on the site of the Mikulčice acropolis itself and in the "rural" burial site at Josefov in the hinterland of the Mikulčice power centre. Based on the incidence of non-metric morphological traits, the population group from the sub-castle area (Kostelisko) is closer to the group from the Mikulčice hinterland (Josefov) than to the individuals from Mikulčice castle. Similarly, the group from Josefov is more akin to the group from Kostelisko than to that from Mikulčice castle. This study supported the previous premise that non-metric traits have a greater predicative value when used to compare smaller population groups originating from a smaller territory.

Key words: non-metric traits – morphology – biological variability – Early Medieval population – Great Moravian period

1. Introduction

Typically, the human skeleton demonstrates extensive variation of structure. This is supported by all sorts of morphological variants of individual bones. A number of these variants are considered to be so-called non-metric, discrete or eventually epigenetic traits. Generally, these involve slight anatomical variants from the common bone structure, which have a certain degree of heritability (the common state most often refers to the most frequently recorded situations within the relevant human population). Traits are predominantly determined genetically. External (environmental) and internal (physiological) factors affect their incidence, but their contribution is not deemed to be decisive. This at least is valid for cranial traits; it is not so unequivocal in the case of post-cranial traits. A number of these traits are associated with the locomotive, physical activity of the individual, i.e. the non-genetic component plays a more prominent role within the heritability of such traits. In the case of traits relating to ligament attachments, one may argue whether their genetic basis predominates or whether their incidence is contingent to physical activity and the stress exerted on the relevant muscle groups. Most non-metric traits have a low population incidence.

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Knowledge regarding the heritability of discrete traits comes mainly from studies on animals, due to the shortage of suitable human samples, i.e. the skeletal remains of biologically related individuals. The ideal study material comprises skeletal remains from family tombs (e.g. Rösing 1986a; Velemínský/Dobisíková 2005; Carson 2006). In general, it is accepted that non-metric morphological traits have greater heritability than classic metric variables, for which the polygenic pattern of inheritance is presumed (e.g. Rösing 1986b; Hauser/DeStafano 1989).

Both facts – genetic basis and low incidence – are a positive factor with regard to the application of non-metric traits when comparing population groups (e.g. Komesu et al. 2007). The predominant opinion is that their predicative value is highest especially for determining the affinity of population groups originating from smaller territories (e.g. Rösing 1986b; Sutter/Mertz 2004; Komesu et al. 2007). Comparison of geographically, chronologically or rather "racially" distant groups has often led to ambiguously interpreted results (e.g. Hallgrímsson et al 2004). Apart from being considered to be indicators of the biological relationships of population groups, they may also inform about evolutionary processes, about the relationship between anatomical modern human and his ancestors (e.g. Manzi/Vienna/Hauser 1996; Manzi/Gracia/Arsuaga 2000). The final degree of conformity of the incidence of non-metric traits may, under certain circumstances, also indicate the biological kinship of individuals (e.g. Alt/Vach 1998; Sjövold 1986; Česnys/Tutkuvienė 2007; Stojanowski et al. 2007).

There exist hundreds of morphological varieties (Saunders 1989). This is not the case of a homogenous group. The discrete character does not apply always and unambiguously. As part of the study of past populations, if we do not take into consideration dental traits, cranial non-metric traits are preferred unequivocally. This is conditional to the aforementioned fact that especially in the case of such traits heritability has been verified and is higher. Cranial traits are also more unequivocally defined and thus their evaluation is less problematic and as groups they are more homogenous. For example, all so-called epigenetic traits are found on the skull.

Attempts to classify traits have existed since the end of the nineteen-sixties (see Ossenberg 1969). If we do not take into consideration the classification according to localisation, i.e. the anatomical division, then traits are most often divided into hyperostotic and hypostotic traits (see Ossenberg 1969, 1977). Traits regarded as hyperostotic are those that have an appearance conditioned by "increased" bone formation. Hypostotic traits, on the other hand, are linked to a shortage of bone tissue, i.e. these are traits whereby bone development is not fully complete and early developmental stages persist into adulthood. The hyperostotic traits, then, include tori (e.g. the mandibular torus), bony bridges (e.g. hypoglossal canal bridging), tubercles (e.g. the precondylar tubercle), as well as vascular and nerve routes in the form of foramina, which occur as a consequence of new bone formation (e.g. the frontal foramen). The hypostotic group includes those changes relating to variations in cranial sutures, i.e. persistent sutures (e.g. the metopic suture), supernumerary ossicles (e.g. the lambda ossicle) or incomplete apertures for vascular and nerve junctions (e.g. oval foramen incompleteness) (e.g. Hanihara/Ishida 2001).

In the Great Moravian population, we used these traits to compare the biological variability of different socio-economic groups – Mikulčice castle, sub-castle and hinterland. The primary goal was to determine the frequency of selected non-metric traits at the largest burial site in the sub-castle area of the Mikulčice power centre, which was uncovered in the Kostelisko position. The relationship between trait incidence and sex, or eventually the preferential laterality of this incidence was tested for all traits.

2. Materials

Based on the incidence of non-metric traits, we compared three population groups.

- The burial site at the Kostelisko position. This is the largest burial site in the sub-castle area of the Mikulčice power centre, where 425 graves have been uncovered. The burial site has not been dug completely. The skeletal remains of around 456 individuals have been found in the graves. Based on the grave equipment, it may be presumed that higher echelons of society were buried here. From a demographic aspect, females and non-adult individuals are more frequently represented. (Velemínský 2000; Velemínský et al. 2005).

- The burial site within the Mikulčice acropolis (castle). The incidence of traits was evaluated in nearly 1000 individuals who were buried principally by the Ist-IInd and IIIrd church (Stloukal 1963, 1964, 1967, 1969; Stloukal/Vyhnánek 1976). It is highly probable that the highest echelons of society lived within the acropolis. Approx. 30 cranial non-metric traits were evaluated (Czarnetzki 1972).
- The burial site at Josefov within the Mikulčice hinterland. Approx. 170 graves were uncovered in this location. It is presumed that a predominantly agrarian, socially weaker section of the Great Moravian population was buried here (Hanáková/Stloukal 1966; Stránská et al. 2002). At the Josefov burial site, a nearly identical group of non-metric traits was studied as in the case of the Kostelisko group (Bartoníček 2000; Unzeitigová 2000).

3. Methods

We evaluated the incidence of roughly one hundred fifty non-metric traits on the skeletons, of which ninety were located on the skulls and sixty-two on the bones of the post-cranial skeleton. Our methodology was based on the work of Finnegan/Faust (1974), Reinhard/Rösing (1985), Czarnetzki et al. (1985), Hauser/DeStefano (1989) and Velemínský (1999). For purposes of subsequent evaluation, we divided the traits into several groups, according to their character or function. This distribution cannot be taken in complete strictness, as the classification of certain traits is problematic. These traits related to:

A - Skull sutures (Epigenetic variants).
B - Presence, absence or nature of foramens – vascular outlets or nerve routes.
C - Presence, absence or nature of joint facets and their alterations.
D - Disorders of ossification, non-junction of the ossification centres or their absence.
Ea - Hyperostotic activity, with the presence of osseous tori, tubercles, spines or bridges.
Eb - Changes in the region of muscle/ligament attachments – loss of bone tissue or fibrous ossification resulting in the genesis of osseous prominences (enthesopathies). This is associated with marked long-term stress acting upon relevant muscle groups. According to Ossenberg (1977) these are termed hypostotic traits.

A list of the studied traits is included in Table 1. The name of the given trait is followed by the abbreviation of the bone, where the given trait was located.

Table 1. List of evaluated non-metric morphological traits.

A. traits related to cranial sutures (epigenetic variants)

sutura metopica
sutura supranalis
fissura metopica
ossiculum metopicum
sutura parametopica
ossiculum suturae coronalis
ossiculum internasalis
ossiculum praefrontale
lamina orbitalis partita
os zygomaticum partitum
fissura zygomatica transversa
sutura infraorbitale
sutura incisiva
ossiculum medianum palatinum anterior
ossiculum medianum palatinum posterior
ossiculum epiptericum
sutura frontotemporalis
processus frontalis ossis temporalis
processus temporalis ossis frontalis

processus parietalis ossis sphenoidalis
ossiculum bregmaticum
ossiculum suturae sagittalis
ossiculum incisurae parietalis
ossiculum parietale partitum
ossiculum suturae squamosae
squama temporalis partialis
sutura. squamomastoidea
processus mastoideus bipartitus
ossiculum lambdae
ossiculum suturae lambdoideae
os Incae
processus interparietalis
sutura mendosa
ossiculum asterii
ossiculum suturae occipitalis

B. Traits related to presence, absence or nature of foramina – outlet of vascular or nerve routes or character of its course („bridging“)

sulcus frontalis
foramen frontale et incisura frontalis
foramen frontale
incisura frontalis
foramen supraorbitale et incisura suprorbitalis
foramen supraorbitale
incisura supraorbitalis
foramen nasale absens
foramen zygomaticum absens
foramen ethmoidale absens
canalis opticus partitus
foramen infraorbitale absens
foramen infraorbitale partitum
foramen parietale absens
foramen parietale inferior
processus parietalis squamae temporalis
foramen squamae superior
foramen mastoideum intrasuturam
foramen mastoideum extrasuturam
foramen tympanicum
foramen occipitale
foramen condylare
canalis condylaris
canalis condylaris intermedius
foramen hypoglossale bipartitum
foramen spinosum incompletum
foramen ovale incompletum
foramen ovale et spinosum confluens
foramen Vesalii
foramen ovale partitum
foramen mentale partitum
foramen mentale absens
foramen mandibulare accessoria
foramen processus transversi partitum C1-7
for.pr.trans.part.C1
for.pr.trans.part.C2
for.pr.trans.part.C3
for.pr.trans.part.C4
for.pr.trans.part.C5
for.pr.trans.part.C6
for.pr.trans.part.C7
foramen processus transversi apartum C1-7
for.pr.trans.apart.C1
for.pr.trans.apart.C2
for.pr.trans.apart.C3
for.pr.trans.apart.C4
for.pr.trans.apart.C5
for.pr.trans.apart.C6
for.pr.trans.apart.C7
ponticuli basales ossis sphenoidalis
processus pterygo-spinosus
processus pterygo-alaris
ponticuli sellae
ponticulus clinoideus medius
ponticulus carotico-clinoideus
ponticuli interclinoidei
taeniae interclinoidae
ponticulus mylohyoideus
ponticuli atlantis
ponticulus atlantis lateralis
ponticulus atlantis. posterior
foramen suprascapulare

C. Traits related to presence, absence or character of joint facets and their changes

facies condylaris bipartita
facies articularis superior partita (C 1)
facies articularis costalis (C7)
facies articularis costalis (L1)
facies articularis sacralis accessoria (Sa, Co)
facies articularis costalis accessoria (Cl)

facies articularis acromialis
facies articularis acromialis absens
facies articularis proccesus coracoidei
facies articularis carpalis partita (Ra)
facies articularis trochlearis partita (Ul)
incisura radialis partita (Ul)
facies lunata partita (Co)
facies Poirieri (Fe)
riding facet (Fe)
facies Charlesi (Fe)
fac.articularis condylaris media (Fe)
facies articularis tibiae accessoria medialis (Ti)
facies articularis tibiae accessoria lateralis (Ti)
facies articularis talaris anterior et media (Ca)
facies articularis talaris anterior et media communis (Ca)
facies articularis talaris anterior bipartita (Ca)
facies articularis talaris media bipartita (Ca)
facies articularis talaris absens (Ca)
facies articularis calcanea anterior et media (Ta)
facies articularis calcanea anterior et media communis (Ta)
facies articularis calcanea anterior absens (Ta)
facies articularis medialis talaris (Ta)
processus trochlearis tali lateralis (Ta)
processus trochlearis tali medialis (Ta)
foramen supratrochleare (Hu)
incisura faciei lunatae (Co)
plate formation (Fe)
fossa Alleni (Fe)

D. Traits related to disorders of ossification, non-junction of the ossification centres or their absence

assimilatio atlantis
ossiculum dens axis
spina bifida sacralis
vertebrae absentes
vertebrae accessoriae
fenestratio sterni
ossiculum acromii
ossiculum coracoideum
ossiculum styloideum radii
ossiculum styloideum ulnae
synostosis acetabuli incompleta
patella multipartita
ossiculum trigonum tali
depressio biparietalis circumscripta

EA. Traits related to hyperostotic activity, with the presence osseous tori, tubercles, spines or bridges

spina trochlearis
tuberculum marginale
tuberculum zygomaxillare
torus palatinus
torus maxillaris
spina suprameatica
depressio suprameatica
torus acusticus
torus occipitalis
processus retromastoideus
tuberculum praecondylare
tuberculum pharyngeum
processus paracondylaris
torus mandibularis
processus supracondylaris
foramen supracondylare
trochanter tertius

EB. Traits related to changes in the area of muscle/ligament attachments – loss of bone tissue or fibrous ossification resulting in the genesis of osseous prominencies (enthesopathies). According to Ossenberg (1977) hypoostotic traits.

fossa pharyngea
linea nuchae suprema
fossa costoclavicularis
fossa pectoralis major
fossa teres
fossa bicipitis
fossa hypotrochanterica
crista hypotrochanterica
fossa gastrocnemica
incisura musculi vasti lateralis (Pa)
fossa musculi vasti lateralis(Pa)
fossa solei
crista solei

We expressed the incidence of bilaterally incident non-metric traits in two forms. As the so-called "average incidence of trait per individual" i.e. the number of individuals with the trait present on one or eventually both sides divided by the total number of individuals evaluated (e.g. Sjøvold 1986). The difference between unilateral and bilateral incidence is thus ignored. This method of expression does not take into account those cases, where only the bone from one side of the body has been preserved. The average incidence of unilateral traits was calculated similarly. Another form of calculation involved the so-called "average incidence on the (non-concrete) side of the skull". Here, the number of sides with the given trait present is divided by the number of sides where this presence could be verified. Thus, in the case of completely preserved skeletons, the number of "cases" doubles. This method, which is most widely used (e.g. Hauser/DeStefano 1989), does not take into consideration the laterality differences of trait incidence. Finally, it is also possible to determine the "average incidence for a concrete side", where the number of "right side" trait incidences is divided by the number of "right side" bones evaluated. The same applies to the left-side manifestation of traits. This process takes into account the difference between unilateral and bilateral incidence, and the laterality of incidence may subsequently enable the inference of the average incidence per individual.

During evaluation, we took into consideration sexual dimorphism, the correlation between the incidence of traits and the age of individuals, and in the case of bilateral traits the preference for a symmetrical/asymmetrical incidence. To verify the difference in the incidence of non-metric traits in both sexes, and to verify the laterality preference in the case of bilateral traits, we used tests for the comparison of nominal traits in independent selection – four-field tables (Tables 2 x 2), Yates correction of the chi square test, Fisher's test of homogeneity and McNemar's test (e.g. Zvára 1998, 1999). The starting null hypothesis presumed that the trait occurs with the same probability in the groups compared. We used the aforementioned tests only to determine whether a concurrence in the incidence does or does not exist, not to determine how great the eventual difference (dependence) of trait frequency is in the groups compared. The test calculations were conducted with the aid of the STATISTICA 5.0 (StatSoft, Inc.) software and Microsoft Excel 2000.

We used the so-called measure of divergence (MD) and mean measure of divergence (MMD) to verify the biological distance between the population groups on the basis of non-metric traits (e.g. Sjøvold 1973, 1977; Zvára 1999). This basically involves the determination of the degree of non-similarity of the measured probabilities (Zvára 1999). We also used this test criterion to verify the probable incidence of traits in groups with different grave equipment. The starting null hypothesis presumes that a trait occurs with the same probability in both compared groups.

If the groups were compared only on the basis of the incidence of one trait, the measure of divergence (MD) was calculated.

$$MD = (\theta_1 - \theta_2) - \left(\frac{1}{n_1} + \frac{1}{n_2}\right)$$

The condition governing its calculation is the arcusin transformation of the average incidence of the trait in both groups.

$$\theta_1 = \arcsin(1 - 2p_1) \qquad \theta_2 = \arcsin(1 - 2p_2)$$

We verified the fact, whether the value of MD is statistically significant at the 95% confidence interval on the basis of the formula (Zvára 1999):

$$MD - 1{,}96\sqrt{s^2_{MD}}\ , \quad MD + 1{,}96\sqrt{s^2_{MD}}$$

Where the value 1.96 is the critical value of normal distribution and s^2_{MD} is the estimate of variance. The variance of the degree of divergence was calculated using the formula:

$$S^2_{MD} = 2\left(\frac{1}{n_1} + \frac{1}{n_2}\right)(2\arcsin(1 - 2p_1) -$$

$$- \arcsin(1 - 2p_2))^2 + \left(\frac{1}{n_1} + \frac{1}{n_2}\right)$$

If among the compared populations there is no difference in the probability of incidence of the trait, the following applies:

$$S^2_{MD} = 2\left(\frac{1}{n_1} + \frac{1}{n_2}\right)^2$$

The confidence interval characterises the interval, which with 95% probability includes the real value of the given parameter. If the null hypothesis applies, then the value of MD has a zero median value, i.e. if the 95% confidence interval for MD includes zero, then at the 5% level of significance the starting null hypothesis cannot be rejected. On the contrary, if it does not include zero, then the null hypothesis is rejected.

When we compared the groups on the basis of trait groups, we calculated the mean measure of divergence (MMD), which is the average of measures of divergence for the individual traits compared. A precondition for the application of MMD is the independence of the traits compared.

$$MMD = \frac{1}{k}\sum_{i=1}^{k}\left[(\arcsin(1-2p_{1i}))^2-\arcsin(1-2p_2))^2 - \left(\frac{1}{n_{1i}}+\frac{1}{n_{2i}}\right)\right]$$

Determination of the 95% confidence interval is the same as in the case of MD. If the interval does not include a zero value, we may conclude that both groups differ in the incidence of traits at the 5% level of significance (Zvára 1999).

Where

$$S_{MMD} = \frac{2}{k^2}\sum_{i=1}^{k}\left(\frac{1}{n_{1i}}+\frac{1}{n_{2i}}\right)\left[2(\arcsin(1-2p_{1i}) - \arcsin(1-2p_{2i}))^2 + \left(\frac{1}{n_{1i}}+\frac{1}{n_{2i}}\right)\right]$$

$$S^2_{MMD} = \frac{2}{k^2}\sum_{i=1}^{k}\left(\frac{1}{n_{1i}}+\frac{1}{n_{2i}}\right)^2$$

Another means of verifying the validity of the concurrence of trait incidence probability in two populations, the statistical provability of the MD (MMD) value, has been previously proposed by Sjøvold (1973):

MD will be significant at the 5% level of significance if the following is true:

$$MD \geq 3\left(\frac{1}{n_1}+\frac{1}{n_2}\right)$$

MD will be significant at the 1% level of significance, if the following is true:

$$MD \geq 6\left(\frac{1}{n_1}+\frac{1}{n_2}\right)$$

As long as we tested the concurrence of two MD values acquired on the basis of the comparison of the incidence of the same trait in three population groups, i.e. the values MD_{12} and $MD_{13,}$ we applied Zvára's procedure (oral communication; Zvára 1999). We proceeded analogically in the case of the values of the mean measure of divergence (MMD_{12} , MMD_{13}).

$$Z = \frac{MD_{12} - MD_{13}}{\sqrt{var_{12} + var_{13} - 2cov}}$$

Where the statistical provability of the difference of both values is determined by the level of probability p (p=0.05, p=0.01, p=0.005).

$$var_{12} = 2^*\left[\frac{1}{n_1}+\frac{1}{n_2}\right]^*\left[2\left(\arcsin(1\text{-}2^*p_1) - (\arcsin(1-2p_2))^2 + \left(\frac{1}{n_1}+\frac{1}{n_2}\right)\right]\right.$$

$$var_{13} = 2^*\left[\frac{1}{n_1}+\frac{1}{n_2}\right]^*\left[2\left(\arcsin(1\text{-}2^*p_1) - (\arcsin(1-2p_3))^2 + \left(\frac{1}{n_1}+\frac{1}{n_3}\right)\right]\right.$$

$$cov = \frac{2}{n1}^*\left[\frac{1}{n_1}+2^*(\arcsin(1\text{-}2p_1)) - (\arcsin(1-2p_2))^* {}^*(\arcsin(1\text{-}2p_1)) - (\arcsin(1-2p_3))\right]$$

4. Results and Discussion

The primary goal of this work was to determine the incidence of non-metric morphological traits in individuals buried at the Kostelisko position and to determine the average frequency of traits for the population group representing the Mikulčice sub-castle. Subsequently, in view of our other objectives, we verified in the case of all traits whether there exist statistically conclusive differences in their incidence among both sexes. This relationship must be kept in mind when we compare population groups with different demographic structures. If there exist statistically significant differences, it is better to exclude the given traits from the comparison, or it is necessary to take this fact into consideration when interpreting results. In the case of bilateral traits, we tested the preference of laterality and symmetrical incidence.

4.1 Non-metric traits in the Mikulčice-Kostelisko group

On the bones from the Mikulčice-Kostelisko burial site, we evaluated the incidence of approximately one hundred fifty non-metric traits, of which around ninety were cranial traits. The average frequencies of individual traits are listed in Table 2. In the case of traits located on paired bones, we calculated not only the average incidence expressed per individual, but also the average incidence of laterality (for a non-specified side).

In the case of the first calculation, relatively frequent situations whereby only one bone out of a pair lacking the trait is preserved are not included, as the presence of the trait on the other side could not be ruled out. If the trait is present, the „individual"is included. The fact whether a trait occurs symmetrically or only unilaterally is thus not taken into consideration. Expression of the incidence of bilateral non-metric traits on a non-specified side testifies to both aforementioned properties. The average population frequencies thus acquired are for this reason always lower. We consider this expression of the average incidence to be more objective. The calculation of the average incidence using various methods is also necessary for the potential comparison with other research.

4.1.1 Relationship between the incidence of non-metric traits and sex.

We verified whether the incidence of a certain trait is influenced by the sex of an individual with the aid of the four-field table, the so-called Yates correction, a modification of the chi-square test for low frequency and Fisher's test. As mentioned previously, this relationship must be taken into consideration when comparing population groups with various demographic structures. The frequency of individual traits in males and females, as well as the values of the test criterion and the relevant level of significance are listed in Table 3. In the case of bilateral traits, we used average "side" frequency for our comparison. Statistically significant values of test criteria are differentiated by the type of script. If the trait was more frequent in males, values are in bold type. If it was more frequent in females, values are in bold italics. If the value *p* in the table is zero (less than 0.001), we exclude the independence of incidence at the 0.001 level of significance. Traits with a statistically different incidence in both sexes are summarised in Table 4.

The incidence of facies *articularis calcanea anterior et media communis* was borderline statistically significant. This, logically in view of the incidence of *facies articularis calcanea anterior et media*, occurred more frequently in females. In the case of analogical traits on the calcaneus, there were no such differences; a junction between the anterior and central calcaneal articular facet was more frequent. A similar situation was also observed in the case of articular surfaces on the posterior side of the lower section of the femur– *facies Charlesi* and *facies articularis condylaris media*. In males, the incidence of an independent *facies Charlesi* was more frequent, while in females the articular surface of the internal condyle- *facies articularis condylaris media* was elongated. These traits are also placed in the context of frequent persistence in a position necessary for the hyper-dorsal flexion

Table 4. Non-metric morphological traits with a statistically different incidence in both sexes.
Explanatory notes: * level of significance p = 0.05 ** level of significance p = 0.01 *** level of significance p = 0.001

incidence more frequent among males			incidence more frequent among females
sutura supranasalis***	proc.trochl.tali lat. (Ta)*	fos. costoclavicularis***	oss. epiptericum*
oss. sut. lambdoideae*	depr. suprameatica***	fos. pectoralis major**	for. hypogl. part.**
vertebrae accessoriae**	spina suprameatica*	fos. bicipitis **	
fac. art. sup. part. (C1)***	torus acusticus***	fos. hypotrochanterica**	
facies Poirieri (Fe)*	torus occipitalis*		
fac. art. calc. ant. et med. (Ta)*	tuberc.praecondylare*		

of the joints between the instep ossicles and phalanges. An example of this may be any activity during which it is necessary to crouch and weight is placed on the knee and ankle (Ubelaker 1979; Capasso et al. 1999).

The results (see Table 4) indicate a generally more frequent incidence of isolated accessory articular facets in males than in females, where the trend is rather towards a prolongation of the articular surface or the fusion of facets. In males, there was also a greater incidence of traits in the areas of ligament/muscle attachments, which are placed in the context of more significant stress being placed on the relevant muscle groups, and of hyperostotic traits.

In females, there was a greater incidence of foramen supratrochleare on the humerus, but this difference was not statistically significant (χ^2 = 2.99).

4.1.2 Bilateral non-metric morphological traits

In the case of bilaterally present morphological traits, there may exist differences in laterality incidence, or a symmetrical incidence may be preferred.

4.1.2.1 Preference of laterality incidence

In traits located on paired bones, the frequency of incidence may be expressed for a concrete side. One may then monitor whether the given trait does not occur more frequently on a certain side. Table 5 includes the average incidence on the right and left side in the case of bilateral traits. This table also contains a verification of laterality preference in incidence, for which we again used the four-field tables and Yates correction, the modification of the chi-square test for low frequency. Apart from this, we also applied McNemar's test, as "both" traits occur on the same object. When using the first two test criteria (depending on frequency), for all traits, no statistically significant difference in incidence on the right and left side was found. McNemar's test showed statistically significant differences in the case of five traits (see Table 6).

4.1.2.2 Asymmetrical incidence of morphological traits

We then verified, whether bilateral non-metric traits occur more often bilaterally (symmetrically) or unilaterally (asymmetrically). Verification of the preference for a symmetrical or asymmetrical

Table 6. Bilateral morphological traits with a statistically preferred incidence on a concrete side.
Explanatory notes: * level of significance, chi-square test p = 0.05 ** level of significance p = 0. 01 *** level of significance p = 0.001

incidence more frequent at right side			incidence more frequent at left side
fac. art. acces. cost. (Cl)**	fac. art. tal. ant. et media com. (Ca) *	for. condylaris	sulcus frontalis ***
	spina suprameatica *		

Table 8. Bilaterally occurring morphological traits with a preferred symmetrical or asymmetrical incidence.
Explanatory notes: see Tab. 6

trait with a preferred symmetrical incidence			trait with a preferred asym-metrical incidence
sutura infraorbitale***	fac. art. tal. ant. et med. com. (Ca)***	tuber. zygomax.***	for. et inc. supraorb.***
sutura incisiva***	fac. art. calc. ant. et med. com. (Ta)***		
	depr. suprameatica***	for. supraorbitale***	
oss. sut. lambdoideae**	inc. fac. lunatae (Co)***	spina suprameatica***	for. hypogl. part.***
fac. art. acromialis**	for. et inc. frontalis***	linea nuchae supr.***	fossa teres*
fac. art. cond. media (Fe)***	incisura frontalis***	crista hypotrochant.**	
fac. art. tib. acc. lat. (Ti)***	for. pr. trans. part. C1-7**		
fac. art. tal. ant. et med. (Ca)***	tuber. marginale***		

incidence is included in Table 7. Listed first are the frequencies of possible combinations of presence/absence. Next, we list the actual values of test criteria with the relevant level of significance (four-field table, Yates correction). A statistically significant preference for symmetrical incidence was found in nineteen morphological traits, while an asymmetrical incidence was more frequent only in the case of four traits (see Table 8).

4.2 Comparison of the Mikulčice power centre and its hinterland on the basis of non-metric traits.

In the following section, we compared the individuals buried at Kostelisko, i.e. in the area of Mikulčice sub-castle, with individuals buried on the territory of the Mikulčice acropolis (Czarnetzki 1972) and the "rural" burial site at Josefov within the hinterland of the Mikulčice power centre (Bartoníček 2000; Unzeitigová 2000), based on the variability of non-metric traits.

4.2.1 Mikulčice sub-castle (Kostelisko) and Mikulčice castle

We first tried to determine whether the occurrence of non-metric traits differs in two probably different socio-economical groups and at the same time within one locality. The comparative data was provided by the research of Czarnetzki (1972), which studied the incidence of around forty morphological traits on the skeletons from Mikulčice burial sites I, II and III (e.g. Stloukal/Vyhnánek 1976). We included twenty-four of these in our evaluation. The basis of his group was formed of individuals buried near the three-aisled basilica (Mikulčice burial site II). Our study, thus basically compares the most extensive burial site on the territory of Mikulčice castle and sub-castle. Both burial sites show from an archaeological aspect a number of analogies (grave inventory, superposition of graves, similar arrangement of burial holes) (e.g. Staňa 1997). From a demographic aspect, though, they are considerably different (index of masculinity, representation of adults/children, average neonatal lifespan etc.) (Velemínský et al. 2005). The demographic indicators support the general premise that the older section of the population, mainly males, lived in the castle.

For comparison, we used the frequency of traits expressed as the average incidence per person (see Table 2). This same method was also used by Czarnetzki (1972) to express incidence. We verified the difference in the incidence of the aforementioned twenty two morphological traits by calculating the measure of divergence (MD). Taking into consideration the determination of the MD confidence interval, we also calculated the variance of this statistical criterion (S^2_{MD}). If the confidence interval did not contain zero, the difference was at the 5% level of significance. Significant values are listed in the table in medium bold type. To verify the statistical significance of MD, we also used the "weaker" test criterion, Sjøvold's procedure (1973). Significant values are then in italics. We consider

Table 10. Comparison of the burial site at Kostelisko with the group of individuals form Mikulčice castle (Czarnetzki 1972) on the basis of the incidence of morphological traits with the aid of the mean measure of divergence. The traits in which both groups differed statistically significantly are in bold type.
Explanatory notes: MMD=mean measure of divergence; S^2_{MMD}= dispersion of MMD; MDD±1,96 S^2_{MMD}=dispersion endpoints

trait group	MMD	S2mmd	MDD-1,96 S2mmd	MDD+1,96 S2mmd
cranial sutures	0,01867	0,00208	-0,07069	0,10803
vessel and nervous foramina	0,45944	0,00589	0,30901	0,60988
hyperostotic traits	0,06653	0,00152	-0,00985	0,14292
areas of muscle/fibrous insertions	0,15312	0,00537	0,00945	0,29678
Total	0,1621	0,00086	0,10469	0,21951

the first method of verification of MD statistical significance to be more conclusive (Table 9).

Results of the comparison of individuals from Kostelisko and the acropolis are listed in Table 9. A statistically significant difference with regards to varaince of the measure of divergence (Zvára 1999) was found in the case of five traits. The greatest difference was in the incidence of the *incisura supraorbitalis*, followed by the foramen infraorbitale partitum, the *foramen hypoglossalis bipartitus*, the *torus acusticus* and the *fossa hypotrochanterica*. According to Sjøvold´s criteria, a further six traits differed in incidence at the same level of significance – the *ossiculum suturae lambdoidea*, the extension of the articular surface of the *caput femoris* on the anterior side of the femoral neck (plate formation, *facies Poirieri*), the foramen supraorbitale, the *fossa pectoralis major et teres*, the *fossa solei*. This means that both groups differed in the incidence of all traits associated with places of muscle/ligament attachment (Table 10).

In the next step, we calculated the mean measures of divergence (MMD) with the help of MD values. The MMD determines the degree of convergence or divergence of the compared groups on the basis of a set of morphological traits. MMD is an average value of MD. We calculated the mean measure of divergence in part on the basis of the MD values of traits of the same character or function, and in part for the whole group of compared traits. With regard to the verification of the level of significance, we once again calculated the variance (S^2_{MMD}) and determined the endpoints of the ninety five percent confidence interval. Similarly as in the case of MD, if the interval did not reach a zero value, we considered the incidence of the group of traits to be different at a 5% level of significance; these values are in medium-bold type (see Table 10). The resulting MMD values show that the compared groups differ in the incidence of traits relating to vascular and nerve apertures and to traits associated with sites of muscle attachments; while the incidence of traits in the area of cranial sutures and those of hyperostotic character is more or less similar (Table 10). The resulting value of the mean measure of divergence is 0.16210. Some authors multiply the values of MMD and MD by one thousand for greater clarity; we then get a value of 162.1.

4.2.2 Mikulčice sub-castle (Kostelisko) and Mikulčice hinterland (Josefov)

The second population group with which we compared the Kostelisko burial site was Josefov. This is a Great Moravian burial site with around 170 graves. It was located approx. ten kilometres northwest of the Mikulčice-Valy locality. It is generally presumed that members of the agricultural settlement were buried here. Compared to the Mikulčice burial site, the grave inventory was very poor. Burials of females and children clearly predominated at this burial site. In view of this fact, hypotheses have been formulated regarding the possible displacement of males into nearby Mikulčice for reasons of work or military service. From a demographic aspect, Kostelisko is not too different from Josefov (Hanáková/Stloukal 1966; Stloukal/Vyhnánek 1976; Stránská et al. 2002), but there exist differences in the representation of graves with a wealthy inventory (for example swords) (Unzeitigová 2000). This is thus a more or less opposite situation to that when comparing Kostelisko with individuals buried in the castle. This comparison was supposed to show to what extent the incidence of morphological non-metric traits differs, despite the geographically close localities. It may be seen as the verification of the concurrence (difference) of people living in the central, "rich" settlement agglomeration and the inhabitants of the smaller, poorer, rural settlement.

The selection of traits evaluated for the Josefov burial site was identical to the traits studied in Kostelisko (Bartoníček 2000; Unzeitigová 2000). The methodology of evaluating individual traits was unified with the authors. We thus had the opportunity to compare both population groups on the basis of nearly all monitored traits; we were able to select also the laterality expression of bilateral traits.

With regards to the comparability of MMD values between Kostelisko and Josefov, which characterise the difference between the inhabitants of Mikulčice castle and Kostelisko or Josefov, we compared both groups on the basis of the same traits, on which the previous comparison had been based. The results are illustrated by Table 11. With regards to the confidence interval, both groups differ at the 5% level of significance in the case of only two traits– torus palatinus and torus acusticus. If we verify the statistical significance of MD using Sjøvold's method, there will be a difference in the incidence of another eight traits (Table 11). The mean measure of divergence has a statistically significant value only on the case of those traits associated with points of muscle/ligament insertion. The resultant mean measure of divergence has a value of 0.08738 (87.4).

Table 12a. Comparison of the burial site at Kostelisko and the burial site at Josefov (Bartoníček 2000; Unzeitigová 2000) using the mean measure of divergence (on the basis of the same traits as in the case of the castle/sub-castle comparison). The traits in which both groups differed statistically significantly are in bold type.
For explanatory notes see Tab. 10.

trait group	MMD	S^2mmd	MDD-1,96 S^2mmd	MDD+1,96 S^2mmd
cranial sutures	**0,29402**	0,005463	0,14916	0,43888
vessel and nervous foramina	0,09566	0,01305	-0,12827	0,31959
hyperostotic traits	**0,39762**	0,00402	0,27336	0,52187
areas of muscle/fibrous insertions	**0,36048**	0,01279	0,13884	0,58211
Total	**0,31234**	0,00204	0,22377	0,4009

Table 12b. Comparison of the burial site at Kostelisko and the burial site at Josefov (Bartoníček 2000; Unzeitigová 2000) using the mean measure of divergence The traits in which both groups differed statistically significantly are in bold type.
For explanatory notes see Tab. 10.

trait group	MMD	S^2mmd	MDD-1,96 S^2mmd	MDD+1,96 S^2mmd
cranial sutures	**0,17384**	0,0021	0,08409	0,26359
ossification' abnormalities	-0,02653	0,02715	-0,34946	0,2964
articular facets	**0,50029**	0,0072	0,33395	0,66664
"disorder" of articular facets	**0,467**	0,01348	0,23944	0,69456
vessel and nervous foramina	**0,4424**	0,00895	0,25703	0,62778
hyperostotic traits	**0,20078**	0,00394	0,07782	0,32375
areas of muscle/fibrous insertions	**0,40092**	0,00542	0,25657	0,54528
Total	**0,32248**	0,00125	0,25321	0,39176

Table 14. Comparison of the population groups from the castle and hinterland (Josefov) using the mean measure of divergence. The traits in which both groups differed statistically significantly are in bold type.
For explanatory notes see Tab. 10.

trait group	MMD	S^2mmd	MDD-1,96 S^2mmd	MDD+1,96 S^2mmd
cranial sutures	0,10939	0,036	-0,0822	0,22700
vessel and nervous foramina	**0,89057**	0,02434	0,58479	1,19635
hyperostotic traits	**0,50288**	0,00525	0,3608	0,64496
the areas of muscle/fibrous insertions	0,3662	0,00288	-0,0687	0,14189
Total	**0,31883**	0,00186	0,2344	0,40325

When we compared the incidence of all monitored morphological traits in the case of both localities, the incidence of the following nine traits was at the 5% level of significance: *facies articularis carpalis partita, facies aricularis trochlearis partita, facies Poirieri, incisura faciei lunatae, canalis condylaris, spina trochlearis, torus palatinus, torus acusticus and crista solei*. With the exception of the *canalis condylaris*, these traits occurred more frequently in Kostelisko. Tables 12a and 12b testifies to the small differences between both localities. Only the mean measure of divergence, calculated on the basis of the incidence of traits relating to the character of joint surfaces, had a statistically significant value. The total MMD is 78.2 (0.07816) that is lower than in the previous case, where the comparison was based only on the smaller group of traits. If we take into consideration that MMD is an average value, then this situation with regard to the individual MDs is logical.

4.2.3 Mikulčice castle and Mikulčice hinterland (Josefov)

We then compared the population groups from the castle and hinterland. The MD value of two traits lay on the 5% statistical level of significance – *torus palatinus* and *trochanter tertius*. In the case of Sjøvold's verification of the level of significance, these groups differ in the incidence of seven traits, including two already mentioned (see Table 13). The mean measure of divergence is significant at the 5% level only for the group of traits with a hyperostotic character. The resulting value of MMD is approximately 99 (0.9891).

Josefov thus again, as in the comparison with Kostelisko, showed a lower incidence of traits that essentially involve hyperostotic activity (tori, tubercles etc.) (Table 14). If we again take into consideration certain previous verifications of the dependence of the incidence of morphological traits on sex (e.g. Česnys 1986), it cannot be ruled out that the small percentual representation of these traits is affected by the demographic composition of the group from Josefov, where females predominate. On the other hand, the index of masculinity in Kostelisko is similarly low (Velemínský et al. 2005).

4.2.4 Mikulčice castle, Mikulčice sub-castle (Kostelisko) and Mikulčice hinterland (Josefov)

Verification of the degree of divergence of MD values acquired on the basis of the comparison of the incidence of the same trait in the Kostelisko, Mikulčice castle and Josefov groups was conducted in accordance with the procedure proposed by K. Zvára (1999, oral communication). We always tested two MD values acquired by comparing one group with two others on the basis of the same trait. For example, the MD value between the groups Kostelisko/castle was compared with the MD determined between Kostelisko and Josefov. The resultant values, so-called Z-criteria- are listed in Tables 15-17.

In table 15, MD is compared between the group from the sub-castle area (Kostelisko) and the group from Mikulčice hinterland (Josefov) and between the group from the sub-castle and the group from Mikulčice castle. In the incidence of *foramen condylaris absens, foramen hypoglossalis bipartitus* and *processus marginalis*, Kostelisko was more remote from the population group from Mikulčice castle than from the burial site at Josefov. In all cases, the difference was at the 1% level of statistical significance. In the case of the *torus palatinus* trait, the situation was opposite. Kostelisko was more remote from Josefov than from the castle group. The difference was approx. at the 5% level of significance. Kostelisko differed from the castle in the incidence of more traits than in the case of the population group from Josefov.

Table 16 contain a comparison of MD values between the group from the Mikulčice hinterland (Josefov) and that from the sub-castle (Kostelisko) and of MD values between the group from the hinterland and Mikulčice castle. In the incidence of *ossicula suturae lambdoideae*, Josefov differed more significantly from Kostelisko than from the group from Mikulčice castle (p=0.05). While in the incidence of the enlargement of the articular surface of the head on the femoral neck, the *foramen condylaris*, the *foramen hypoglossalis bipartitus* and the *processus marginalis* (p=0.001) there was a more significant difference between

Table 15. Verification of the differences in MD values acquired by comparing the population group from the sub-castle (Kostelisko) with the burial site at Josefov (Bartoníček 2000; Unzeitigová 2000) and with individuals from Mikulčice castle (Czarnetzki 1972).
Explanatory notes: n=number of individuals; x=number of cases, where the trait occurred; MD12=measure of divergence between the 1st and 2nd group, MD13= measure of divergence between the 1st and 3rd group; Z-criterion; p=level of significance reached

	Mikulčice sub-castle (Kostelisko)		Mikulčice-hinterland (Josefov)		Mikulčice-castle					
	n1	x1	n2	x2	n3	x3	MD12	MD13	Z	p
sutura metopica	297	23	117	12	967	98	0,0050	0,0112	-0,2606	0,7944
oss. sut. coronalis	151	4	86	11	698	30	0,3370	0,0088	3,1448	0,0017
oss. epiptericum	75	19	54	18	394	76	0,0751	0,0437	0,3166	0,7515
sut. frontotemp.	121	3	51	1	457	12	-0,0251	-0,0103	-0,3629	0,7167
oss. bregmatic.	217	1	93	-	719	1	-0,0089	0,0005	-0,2526	0,8006
oss. sut. sagittal.	180	13	103	10	692	30	0,0024	0,0254	-0,5326	0,5943
oss. lambdae	99	20	87	13	702	125	0,0273	-0,0017	0,6583	0,5103
oss. sut. lambdoid.	175	42	89	44	658	281	1,9394	0,6767	10,3673	0,0000
fac. condyl. bipartita	87	5	43	3	476	10	-0,0291	0,0643	-1,2549	0,2095
enlargement of cap. femoris	53	19	53	5	406	210	1,2167	0,1803	3,1422	0,0017
for.et inc. suprorb.	210	19	98	4						
for. ethmoidale absens	101	2	39	2	241	4	0,0275	-0,0127	0,4723	0,6367
for. infraorb. absens	115	-	80	2			......			
for. condylaris absens	126	35	49	7	545	477	0,0839	1,7045	-4,9057	**0,0000**
for. hypogl. bipart.	179	50	52	13	546	15	-0,0204	0,6020	-4,7159	**0,0000**
proc. marginalis absens	161	44	50	10	521	483	0,0037	2,2253	-7,4069	**0,0000**
torus palatinus	221	44	71	1	605	147	0,4535	0,0050	2,2786	**0,0227**
torus acusticus	217	41	75	3	882	33	0,2287	0,2544	-0,2100	0,8336
tuberc. pharyng. absens	196	55	56	19	583	194	-0,0068	0,0060	-0,2682	0,7886
troch. tertius	84	20	39	4	668	194	0,0975	0,0007	0,5804	0,5616
linea nuchae supr.	94	39	81	21						
fossa pector.maj.	121	12	64	13	760	98	0,0627	-0,0008	0,7173	0,4732
fossa teres	128	11	62	8	748	111	-0,0044	0,0292	-0,6548	0,5126
fossa hypotroch.	160	18	66	24	824	349	0,3513	0,5301	-1,0997	0,2715
fossa solei	99	28	67	14	733	129	0,0046	0,0539	-0,8326	0,4050

Table 16. Verification of the differences in MD values acquired by comparing the population group from the hinterland (Josefov) (Bartoníček 2000; Unzeitigová 2000) with Kostelisko and with individuals from Mikulčice castle (Czarnetzki 1972).
Explanatory notes: see Tab. 15

	Mikulčice-hinterland (Josefov)		Mikulčice-sub-castle (Kostelisko)		Mikulčice-castle					
	n1	x1	n2	x2	n3	x3	MD12	MD13	Z	p
sutura metopica	117	12	297	23	967	98	-0,0042	-0,0096	0,2364	0,8132
oss. sut. coronalis	86	11	151	4	698	30	0,1454	0,0854	0,7908	0,4290
oss. epiptericum	54	18	75	19	394	76	-0,0008	0,0823	-1,0909	0,2753

	Mikulčice-hinterland (Josefov)		Mikulčice-subcastle (Kostelisko)		Mikulčice-castle					
	n1	x1	n2	x2	n3	x3	MD12	MD13	Z	p
sut. frontotemp.	51	1	121	3	457	12	-0,0266	-0,0198	-0,2123	0,8319
oss. bregmatic.	93	-	217	1	719	1	0,0031	-0,0066	0,3345	0,7380
oss. sut. sagittal.	103	10	180	13	692	30	-0,0072	0,0347	-1,1282	0,2592
oss. lambdae	87	13	99	20	702	125	-0,0024	-0,0069	0,1090	0,9132
oss. sut. lambdoid.	89	44	175	42	658	281	0,2699	0,0055	2,2135	**0,0269**
fac. condyl. bipartita	43	3	87	5	476	10	-0,0322	0,0340	-0,8829	0,3773
enlargement of cap. femoris	53	5	53	19	406	210	0,3972	0,9408	-2,3743	**0,0176**
for. et inc.suprorb.	98	4	210	19						
for. ethmoidale absens	39	2	101	2	241	4	-0,0051	0,0096	-0,2454	0,8062
for. infraorb.absens	80	2	115	-						
for. condylaris absens	49	7	126	35	545	477	0,0839	2,6817	-6,4092	**0,0000**
for. hypogl. bipart.	52	13	179	50	546	15	-0,0204	0,4890	-2,2477	**0,0246**
proc.marginalis absens	50	10	161	44	521	483	0,0037	2,7582	-6,1364	**0,0000**
torus palatinus	71	1	221	44	605	147	0,4535	0,6131	-1,3618	0,1733
torus acusticus	75	3	217	41	882	33	0,2287	-0,0143	1,7735	0,0761
tuberc. pharyng.absens	56	19	196	55	583	194	-0,0068	-0,0194	0,2966	0,7668
troch. tertius	39	4	84	20	668	194	0,0975	0,2093	-1,0684	0,2854
linea nuchae supr.	81	21	94	39						
fossa pector.maj.	64	13	121	12	760	98	0,0627	0,0233	0,5977	0,5500
fossa teres	62	8	128	11	748	111	-0,0044	-0,0143	0,1607	0,8724
fossa hypotroch.	66	24	160	18	824	349	0,3513	-0,0013	1,7103	0,0872
fossa solei	67	14	99	28	733	129	0,0046	-0,0093	0,1782	0,8585

Table 17. Verification of the differences in MD values acquired by comparing individuals from Mikulčice castle (Czarnetzki 1972) with the burial site at Josefov (Bartoníček 2000; Unzeitigová 2000) and with the burial site at Kostelisko. Explanatory notes: see tab. 15

	Mikulčice-subcastle (Kostelisko)		Mikulčice-hinterland (Josefov)		Mikulčice-castle					
	n1	x1	n2	x2	n3	x3	MD12	MD13	Z	p
sutura metopica	967	98	297	23	117	12	0,0026	-0,0096	0,6570	0,5112
oss. sut. coronalis	698	30	151	4	86	11	0,0002	0,0854	-1,0828	0,2789
oss. epiptericum	394	76	75	19	54	18	0,0053	0,0823	-0,7531	0,4514
sut. frontotemp.	457	12	121	3	51	1	-0,0104	-0,0198	0,2601	0,7948
oss. bregmatic.	719	1	217	1	93	-	-0,0022	-0,0066	0,1561	0,8760
oss. sut. sagittal.	692	30	180	13	103	10	0,0085	0,0347	-0,5226	0,6012
oss. lambdae	702	125	99	20	87	13	-0,0078	-0,0069	-0,0260	0,9792
oss. sut. lambdoid.	658	281	175	42	89	44	0,1531	0,0055	1,8097	0,0703
fac. condyl. bipartita	476	10	87	5	43	3	0,0238	0,0340	-0,1089	0,9133
enlargement of cap. femoris	406	210	53	19	53	5	0,0820	0,9408	-2,9203	**0,0035**
for. et inc. suprorb.			210	19	98	4				
for. ethmoidale absens	241	4	101	2	39	2	-0,0135	0,0096	-0,2826	0,7774
for. infraorb. absens			115	-	80	2				

	Mikulčice-sub-castle (Kostelisko)		Mikulčice-hinter-land (Josefov)		Mikulčice-castle					
	n1	x1	n2	x2	n3	x3	MD12	MD13	Z	p
for. condylaris absens	545	477	124	57	49	7	0,8540	2,6817	-3,6298	**0,0003**
for. hypogl. bipart.	546	15	179	50	52	13	0,6020	0,4890	0,4871	0,6262
proc. marginalis absens	521	483	161	44	50	10	2,2253	2,7582	-1,0085	0,3132
torus palatinus	605	147	221	44	71	1	0,0050	0,6131	-3,0668	**0,0022**
torus acusticus	882	33	217	41	75	3	0,2544	-0,0143	3,3578	**0,0008**
tuberc. pharyng. absens	583	194	196	55	56	19	0,0060	-0,0194	0,7226	0,4699
troch. tertius	668	194	84	20	39	4	0,0007	0,2093	-1,2567	0,2089
linea nuchae supr.			94	39	81	21				
fossa pector.maj.	760	98	121	12	64	13	-0,0008	0,0233	-0,3795	0,7043
fossa teres	748	111	128	11	62	8	0,0292	-0,0143	0,9124	0,3615
fossa hypotroch.	824	349	160	18	66	24	0,5301	-0,0013	4,0997	0,0000
fossa solei	733	129	99	28	67	14	0,0539	-0,0093	0,9983	0,3182

Josefov and the series of skeletal remains from the castle than between Josefov and Kostelisko. The population group from the Mikulčice hinterland (Josefov) thus differs from the castle group in the incidence of more traits than from the sub-castle group.

The final results of the MD comparison between the skeletal groups from Mikulčice castle and the other two groups form the basis of Table 17. The group from the castle differed significantly from the sub-castle group (Kostelisko) than from the hinterland group (Josefov) in the incidence of *torus acusticus* (0.01) and *fossa hypotrochanterica* (p=0.001). On the contrary, it differed more from Josefov in the incidence of the elongation of *caput femoris* (p=0.01), *foramen condylaris* (0.001) and *torus palatinus* (0,01). The population group from the castle differed statistically from the Kostelisko group in the incidence of two traits, and from the Josefov group in the incidence of three traits, i.e. its difference from both groups is similar.

5. Summary

If we were to summarise all of the above, then the following apply:

- we studied approximately 155 non-metric morphological traits on the skeletons from the Mikulčice-Kostelisko burial site
- in view of the goal of this work, we divided the non-metric traits into five groups according to their character or function
- the relationship between incidence and sex was demonstrated in these traits; in males, *sutura supranasalis, depressio suprameatica, fossa costoclavicularis, facies articularis superior partita, torus acusticus* (p=0.001), *fossa pectoralis major, fossa hypotrochanterica, fossa bicipitis, vertebrae accessoriae* (p=0.01), *ossicula suturae lambdoideae, facies Poirieri, facies articularis calcanea anterior et media, processus trochlearis tali lateralis, spina suprameatica, torus occipitalis and tuberculum praecondylare* (p=0.05) occurred more frequently; in females, *foramen hypoglossale partitum* and *ossiculum epiptericum* occurred more frequently
- in males, non-metric traits associated with changes at the site of muscle attachments and hyperostotic traits occurred more frequently
- in males, isolated articular accessory facets occurred more frequently; in females, there was rather a tendency towards elongation, fusion of the articular surface (*facies articularis calcanea anterior et media* resp. *facies articularis calcanea anterior et media communis*; *facies Charlesi* or *facies condylaris media*)

- a clear preference for the incidence on a concrete side was not demonstrated in any of the bilaterally occurring traits
- a symmetrical incidence was significantly more frequent in the following bilateral traits – *sutura infraorbitale, sutura incisiva, facies articularis calcanea anterior et media, facies articularis calcanea anterior et media communis, facies articularis talaris anterior et media*, *depressio et spina suprameatica, tuberculum zygomaxillare, facies condylaris media, facies articularis tibiale accessoria lateralis, incisura frontalis, tuberculum marginale, linea nuchae suprema, crista hypotrochanterica* (p=0.001), *incisura faciei lunatae* and *ossicula suturae lambdoideae, facies articularis acromialis, crista hypotrochanterica* (p=0.01)
- an asymmetrical incidence was more frequent only in the case of the *foramen suparorbitale*, *foramen hypoglossalis partitum* (p=0.001), *fossa teres* (p=0.05)
- the burial sites at Kostelisko, in the sub-castle of the Mikulčice power centre differed statistically significantly from the Mikulčice castle group in the incidence of: *incisura supraorbitalis, foramen infraorbitale partitum, foramen hypoglossalis bipartitus, torus acusticus* and *fossa hypotrochanterica* (p=0.05)
- the burial site at Kostelisko differed statistically significantly from the burial site at Josefov in the Mikulčice hinterland in the incidence of *torus palatinus* and *torus acusticus* (p=0.05)
- the population group from Mikulčice castle differed statistically significantly from the burial site at Josefov in the incidence of *torus palatinus* and *trochanter tertius* (p=0.05);

- if we compare the groups from Mikulčice castle, sub-castle and hinterland, the following apply:
  - Kostelisko differed from Mikulčice castle in the incidence of traits relating to vascular and nerve apertures and in the incidence of the group of traits associated with sites of muscle attachment
  - Josefov differed from the other two groups in the incidence of traits with a hyperostotic character.
  - Mikulčice castle significantly differed from Kostelisko in the incidence of two traits, and from Josefov in the incidence of three traits;
- if we compare the values of the measure of divergence for all comparisons, the following apply:
  - Kostelisko significantly differed from Josefov only in the incidence of one trait, while it differed from Mikulčice castle in the incidence of three traits
  - Josefov differed significantly from Kostelisko in the incidence of one trait, while it differed from Mikulčice castle in the incidence of four traits
  - Summary of the values of the mean measure of divergence MMD:
    Kostelisko – Josefov
    87.4 (S^2_{mmd} = 0.00197)
    Mikulčice castle – Josefov
    98.9 (S^2_{mmd} = 0.00231)
    Kostelisko – Mikulčice castle
    162.1 (S^2_{mmd} = 0.00086)

According to the incidence of non-metric morphological traits, the population group from the sub-castle area (Kostelisko) is closer to the group from Mikulčice hinterland (Josefov) than to individuals from Mikulčice castle. Similarly, the group from Josefov is more similar to that from Kostelisko than to the group from Mikulčice castle.

6. Conclusion

There exist tens of non-metric morphological traits, but not all have the same predictive value, an unequivocal methodology of evaluation. Naturally, the selection of traits has a fundamental importance for the comparison of population groups. If we are to compare three groups on the basis of two different groups of traits, it is not improbable that we will acquire completely different results. The fact that the group from Kostelisko was compared with the Josefov group (Bartoníček 2000; Unzeitigová 2000) and with the Mikulčice castle group (Czarnetzki 1972) on the basis of a more or less same group of non-metric traits may be considered to be a positive aspect of this study. This fact is not that usual. In Central Europe, the incidence of non-metric traits has been studied on only very few skeletal series. From this aspect, only the series from the Great Moravian era has been systematically processed within the territory of our country. Apart from the series compared in this study, this includes the burial site at Dolní Věstonice (e.g. Hrnčířová 2007). Naturally, the insufficient preservation and representation of skeletal remains in prehistoric burial sites is a limiting factor. It would be meaningful to complexly evaluate the incidence of non-metric traits for the whole prehistoric period, or the archaeological culture.

Attempts at "categorisation", the division of non-metric traits exist since the time, when they were used for population comparisons as a "group of traits" (see Ossenberg 1969, 1977). In view of their diversity, every division or classification is problematic. This also applies in the case of dividing traits into groups according to similarities in character, function or location, which we applied in this work. Comparison of the Great Moravian population groups ultimately showed a difference only in the case of such defined groups (e.g. Table 10). The suitability of this approach will be borne out only by subsequent research.

This study supported the previous premise that non-metric traits have a greater predicative value when used to compare smaller population groups originating from a smaller territory (e.g. Rösing 1986b) than when used to compare geographically, chronologically or racially or ethnic groups.

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Table 2. Incidence of non-metric traits, expressed as average per individual and per non-specific side in the case of bilateral traits.

trait	Incidence on Individual			Incidence on Side		
	N	Incidence	%	N	Incidence	%
sutura metopica	297	23	7,7			
sutura supranalis	216	132	61,1			
fissura metopica	261	4	1,5			
ossiculum metopicum	262	-	-			
sut. parametop.	217	-	-	492	-	-
oss. sut. coronalis	151	4	2,6	341	4	1,2
ossiculum internasalis	93	-	-			
ossiculum praefrontale	98	3	3,1	208	3	1,4
lam. orbit. partita	11	1	9,1	45	1	2,2
oss. zygom. part.	138	3	2,2	382	3	0,8
fiss. zygom. transv.	113	9	8,0	319	13	4,1
oss. sut. zygo-max.	117	6	5,1	313	6	1,9
sut. infraorbitale	139	109	78,4	248	161	64,9
sutura incisiva	220	89	40,5	446	163	36,5
oss. med. palat. anter.	224	-	-			
oss. med. palat. post.	210	-	-			
oss. epipтericum	75	19	25,3	173	25	14,5
sut. frontotemp.	121	3	2,5	305	3	1,0
proc. front. os. temp.	92	7	7,6	245	9	3,7
proc. temp. os. front.	89	2	2,2	241	3	1,2
proc. pariet. os. sphen.	74	20	27,0	181	27	14,9
oss. bregmatic.	217	1	0,5			
oss. sut. sagittal.	180	13	7,2			
oss. inc. pariet.	106	17	16,0	257	20	7,8
os pariet. part.	188	-	-	438	-	-
oss. sut. squam.	53	1	1,9	164	2	1,2
sq. tempor. part.	103	2	1,9	303	3	1,0
sut. squamom.	148	29	19,6	373	38	10,2
proc. mast. bipart.	115	8	7,0	322	9	2,8
oss. lambdae	99	20	20,2			
oss. sut. lambdoid.	175	133	76,0	304	199	65,5
os Incae	244	3	1,2			
proc. interpariet.	232	4	1,7			
sut. mendosa	140	3	2,1	322	5	1,6
oss. asterii	109	10	9,2	256	14	5,5
oss. sut. occipit.	93	8	8,6	222	9	4,1
assimilatio atlantis	141	1	0,7			
oss. dens axis	137	1	0,7			
spina bifida sacralis	74	4	5,4			

trait	Incidence on Individual			Incidence on Side		
	N	Incidence	%	N	Incidence	%
vert. absentes	43	1	2,3			
vert. accessoriae	44	5	11,4			
fenestratio sterni	45	-	-			
oss. acromii	42	1	2,4	109	1	0,9
oss. coracoid.	45	-	-	136	-	-
oss. styl. radii	33	-	-	111	-	-
oss. styl. ulnae	17	-	-	63	-	-
synost. acet. incompl. (co)	110	-	-	245	-	-
patella multipartita	45	-	-	142	-	-
oss. trigon. tali (Ta)	99		-	250	-	-
fac. condyl. bipartita	87	5	5,7	215	7	3,3
fac. art. sup. part. (C1)	99	26	26,3	203	37	18,2
fac. art. cost. C7	55	1	1,8	126	1	0,8
fac. art. cost. L1	38	-	-	87	-	-
fac. art. sacral. acces. (Sa)	30	5	16,7	66	6	9,1
fac. art. sacr. acc. (Co)	50	8	16,0	116	9	7,8
fac. art. acces. cost. (Cl)	128	85	66,4	228	123	53,9
fac. art. acromialis	38	37	97,4	58	55	94,8
fac. art. acromialis absens	22	4	18,2	58	5	8,6
fac. art. proc.corac.	31	13	41,9	86	17	19,8
fac. art. carp. part. (Ra)	44	8	18,2	122	11	9,0
fac. art. trochl. part. (Ul)	63	30	47,6	138	44	31,9
inc. radial. part. (Ul)	50	2	4,0	139	2	1,4
fac. lunata part. (Co)	108	-	-	244	-	-
facies Poirieri (Fe)	53	12	22,6	141	17	12,1
riding facet (Fe)	93	-	-	251	-	-
facies Charlesi (Fe)	66	34	51,5	137	52	38,0
fac. art. cond. media (Fe)	68	40	58,8	135	61	45,2
facies Charlesi+fac. art. cond. media (Fe)	133	73	54,9	272	113	41,5
fac. art. tib. acc. med. (Ti)	30	6	20,0	91	7	7,7
fac. art. tib. acc. lat. (Ti)	70	63	90,0	112	87	77,7
fac. art. tal. ant. et med. (Ca)	135	75	55,6	268	120	44,8
fac. art. tal. ant. et med. com. (Ca)	146	96	65,8	274	156	56,9
fac. art. tal. ant. bipart. (Ca)	124	1	0,8	286	1	0,3
fac. art. tal. med. bipart. (Ca)	129	-	-	292	-	-
fac. art. tal. ant. absens (Ca)	126	9	7,1	280	10	3,6
fac. art. calc. ant. et med. (Ta)	125	30	24,0	271	44	16,2
fac. art. calc. a. et m. com. (Ta)	153	137	89,5	272	227	83,5
fac. art. calc. ant. absens (Ta)	114	3	2,6	274	4	1,5
fac. art. med. tal. (Ta)	59	4	6,8	171	6	3,5
proc. troch. tali lat. (Ta)	77	10	13,0	194	14	7,2

trait	Incidence on Individual			Incidence on Side		
	N	Incidence	%	N	Incidence	%
proc. troch. tali med.(Ta)	42	36	85,7	70	49	70
for. supratroch. (Hu)	100	28	28,0	226	35	15,5
inc. fac. lunatae (Co)	105	32	30,5	228	54	23,7
plate formation (Fe)	49	7	14,3	140	11	7,9
fossa Alleni (Fe)	65	4	6,2	187	5	2,7
sulcus frontalis	153	77	50,3	309	107	34,6
for. et inc.supratr.	211	2	0,9	484	2	0,4
for. et inc. frontalis	253	242	95,7	453	412	90,9
foramen frontale	218	69	31,7	443	91	20,5
incisura frontalis	239	212	88,7	422	336	79,6
for. et inc. suprorb.	210	19	9,0	476	19	4,0
foramen supraorb.	213	17	8,0	486	17	3,5
incisura supraorb.	210	1	0,5	496	2	0,4
for. nasale absens	80	11	13,8	165	14	8,5
for. zygomat. absens	158	22	13,9	392	24	6,1
for. ethmoidale	101	99	98,0	169	164	97,0
can. opticus part.	83	1	1,2	198	1	0,5
for. infraorb. absens	115	-	-	303	-	-
for. infraorb. part.	116	8	6,9	292	12	4,1
for. pariet. absens	185	131	70,8	327	190	58,1
for. pariet. inf.	100	-	-	257	-	-
proc. pariet. sq. temp.	74	2	2,7	218	3	1,4
for. squam. sup.	78	3	3,8	243	4	1,6
for. mastoid. intras.	83	51	61,4	176	68	38,6
for. mastoid. extras.	115	88	76,5	193	112	58,0
for. tympan.	191	31	16,2	432	41	9,5
for. marginale	191	17	8,9	448	19	4,2
for. occipitale	174	22	12,6			
for. condylare	126	91	72,2	232	126	54,3
can. condylaris	124	67	54,0	243	92	37,9
can. condyl. interm.	114	4	3,5	278	4	1,4
for. hypogl. bipart.	179	50	27,9	359	55	15,3
for. spin. incompl.	76	31	40,8	185	41	22,2
for. ovale incompl.	96	3	3,1	257	5	1,9
for. ovale et spin. confl.	99	3	3,0	262	4	1,5
for. Vesalii	110	21	19,1	275	30	10,9
for. ovale part.	108	2	1,9	289	4	1,4
for. mentale part.	253	1	0,4	545	2	0,4
for. mentale absens	251	1	0,4	540	2	0,4
sulc. myloh. absens	161	2	1,2	420	4	1,0

trait	Incidence on Individual			Incidence on Side		
	N	Incidence	%	N	Incidence	%
for. mandib. access.	132	17	12,9	349	21	6,0
for. pr. trans. part. C1-7	52	49	94,2	77	69	89,6
for. pr. trans. part. C1	37	1	2,7	117	1	0,9
for. pr. trans. part. C2	66	2	3,0	160	2	1,25
for. pr. trans. part. C3	45	-	-	123	-	-
for. pr. trans. part. C4	54	5	9,3	131	5	3,8
for. pr. trans. part. C5	54	22	40,7	126	31	24,6
for. pr. trans. part. C6	56	42	75,0	106	60	56,6
for. pr. trans. part. C7	30	9	30,0	79	10	12,7
for. pr. trans. apart. C1-7	9	5	55,6	28	8	28,6
for. pr. trans. apart. C1	35	3	8,6	109	5	4,6
for. pr. trans. apart. C2	65	3	4,6	157	4	2,5
for. pr. trans. apart. C3	39	-	-	116	-	-
for. pr. trans. apart. C4	48	-	-	128	-	-
for. pr. trans. apart. C5	44	-	-	129	-	-
for. pr. trans. apart. C6	37	-	-	106	-	-
for. pr. trans. apart. C7	29	1	3,4	86	1	1,2
pont. os. sphenoid.	99	8	8,1	239	8	3,3
proc. pter.-spinos.	94	3	3,2	241	3	1,2
proc. pter.- alaris	100	7	7,0	246	7	2,8
ponticuli sellae	80	14	17,5	169	23	13,6
pont. clinoid medius	91	12	13,2	188	18	9,6
pont. carot.-clinoid.	88	5	5,7	186	6	3,2
pont. interclinoid.	108	2	1,9	231	3	1,3
taenie interclinoid.	100	1	1,0	214	2	0,9
pont. mylohyoid.	158	12	7,6	400	13	3,3
pont. atlantis	76	6	7,9	180	8	4,4
pont. atlantis lat.	83	1	1,2	200	2	1
pont. atlantis post.	84	6	7,1	196	8	4,1
for. suprascap.	78	7	9,0	207	8	3,9
depr. bipar. circum.	235	-	-	515	-	-
spina trochlearis	149	38	25,5	329	51	15,5
tuberc. marginale	161	117	72,7	321	173	53,9
tuberc. zygomax.	106	37	34,9	275	56	20,4
torus palatinus	221	44	19,9			
torus maxillaris	201	4	2,0	445	5	1,1
depres. suprameat.	204	113	55,4	407	172	42,3
spina suprameat.	205	111	54,1	406	170	41,9
torus acusticus	217	41	18,9	476	62	13,0
torus occipitalis	208	23	11,1			
proc. retromast.	122	7	5,7	279	12	4,3

trait	Incidence on Individual			Incidence on Side		
	N	Incidence	%	N	Incidence	%
tuberc. praecond.	161	8	5,0	339	11	3,2
tuberc. pharyng.	196	141	71,9			
proc. paracond.	53	2	3,8	136	2	1,5
torus mandibul.	249	3	1,2	536	5	0,9
proc. supracond.	134	2	1,5	322	3	0,9
for. supracond.	156	-	-	365	-	-
troch. tertius	84	20	23,8	204	28	13,7
fossa pharyng.	185	44	23,8			
linea nuchae supr.	94	39	41,5	191	75	39,3
fossa costaclavic.	113	35	31,0	247	48	19,4
fossa pector.maj.	121	12	9,9	305	17	5,6
fossa teres	128	11	8,6	312	12	3,8
fossa bicipitis	66	17	25,8	172	21	12,2
fossa hypotroch.	160	18	11,3	360	29	8,1
crista hypotroch.	125	57	45,6	247	85	34,4
fossa gastrocn.	72	6	8,3	164	9	5,5
inc. musc. vasti lat.(Pa)	41	12	29,3	125	16	12,8
fossa. musc. vasti lat.	41	-	-	138	-	-
fossa solei	99	28	28,3	253	43	17,0
crista solei	83	36	43,4	189	51	27,0

Table 3. Frequency of non-metric traits in male and female and verification of sexual differences using the Chi-square test, Yates correction or Fisher test.
Explanatory notes: traits for which statistically significant differences have been demonstrated are in bold type; in the case of higher incidence of traits in female they are in bold italics.

trait	Male			Female			χ2 test		Yates'correction	
	N	Incidence	%	N	Incidence	%	χ2	p	χ2	p
sutura metopica	72	5	6,9	125	6	4,8	0,4	0,528	0,1	0,757
sutura supranalis	**61**	**54**	**88,5**	**93**	**48**	**51,6**	**22,4**	**0**	**20,82**	**0**
fissura metopica	68	-	-	116	2	1,7	1,2	0,276	0,12	0,725
ossiculum metopicum	69	-	-	114	-	-				
sut. parametop.	130	-	-	216	-	-				
oss.sut. coronalis	102	2	2,0	160	2	1,3	0,2	0,647	-	0,953
ossiculum internasale	31	-	-	48	-	-				
ossiculum praefrontale	67	-	-	103	3	2,9	2,0	0,159	0,66	0,416
lam. orbit. partita	11	-	-	21	-	-				
oss. zygom. part.	101	-	-	167	2	1,2	1,2	0,270	0,14	0,710
fiss. zygom. transv.	87	3	3,4	139	6	4,3	0,1	0,745	-	0,980
oss. sut. zygo-max.	88	1	1,1	149	4	2,7	0,6	0,423	0,11	0,739
sut. infraorbitale	61	33	54,1	98	58	59,2	0,4	0,529	0,22	0,642
sutura incisiva	117	28	23,9	192	41	21,4	0,3	0,598	0,15	0,699

trait	Male			Female			χ2 test		Yates'correction	
	N	Incidence	%	N	Incidence	%	χ2	p	χ2	p
oss. med. palat. anter.	57	-	-	95	-	-				
oss. med. palat. post.	51	-	-	89	-	-				
oss. epiptericum	***66***	***5***	***7,6***	***85***	***16***	***18,8***	***3,9***	***0,048***	***3,04***	***0,081***
sut. frontotemp.	81	-	-	147	2	1,4	1,1	0,292	0,1	0,755
proc. front. os. temp.	76	3	3,9	119	3	2,5	0,3	0,574	0,02	0,891
proc. temp. os. front.	77	-	-	116	3	2,6	2,0	0,155	0,69	0,408
proc. pariet. os. sphen.	66	14	21,2	88	13	14,8	1,1	0,298	0,68	0,409
oss. bregmatic.	63	-	-	105	-	-				
oss. sut. sagittal.	42	2	4,8	89	8	9,0	0,7	0,395	0,25	0,619
oss. inc. pariet.	84	8	9,5	129	11	8,5	0,1	0,803	0	0,997
os pariet. part.	110	-	-	201	-	-				
oss. sut. squam.	57	2	3,5	79	-	-	2,8	0,935	0,91	0,339
sq. tempor. part.	82	2	2,4	138	1	0,7	1,1	0,289	0,21	0,646
sut. squamom.	62	5	8,1	149	12	8,1	-	0,998	0,08	0,783
proc. mast. bipart.	87	6	6,9	132	2	1,5	4,3	0,378	2,92	0,874
oss. lambdae	13	3	23,1	40	9	22,5	-	0,966	0,11	0,735
oss. sut. lambdoid.	**74**	**52**	**70,3**	**142**	**80**	**56,3**	**3,97***	**0,046**	**3,41**	**0,065**
os Incae	62	1	1,6	100	1	1	0,12	0,731	0,15	0,698
proc. interpariet.	57	-	-	99	3	3,0	1,76	0,185	0,32	0,471
sut. mendosa	97	3	3,1	141	2	1,4	0,78	0,376	0,18	0,671
oss. asterii	86	4	4,7	129	6	4,7	-	1,000	0,11	0,741
oss. sut. occipit.	79	3	3,8	107	6	5,6	0,32	0,570	0,05	0,824
assimilatio atlantis	37	-	-	72	1	1,4	0,52	0,471	0,12	0,733
oss. dens axis	40	1	2,5	75	-	-	1,89	0,169	0,1	0,748
spina bifida sacralis	27	2	7,4	41	1	2,4	0,95	0,329	0,14	0,709
vert. absentes	20	-	-	21	1	4,8	0,98	0,323	-	0,980
vert. accessoriae	**18**	**5**	**27,8**	**24**	**0**	**0**	**7,57**	**0,059**	**5,15**	**0,023**
fenestratio sterni	17	-	-	24	-	-				
oss. acromii	36	-	-	70	1	1,4	0,52	0,471	0,12	0,734
oss. coracoid.	50	-	-	84	-	-				
oss. styl. radii	46	-	-	63	-	-				
oss. styl. ulnae	23	-	-	39	-	-				
synost. acet. incompl. (Co)	98	-	-	138	-	-				
patella multipartita	50	-	-	83	-	-				
oss. trigon. tali (Ta)	76	-	-	154	-	-				
fac. condyl. bipartita	68	5	7,4	132	2	1,5	4,53	0,3333	2,96	0,0851
fac. art. sup. part. (C1)	**59**	**22**	**37,3**	**111**	**14**	**12,6**	**14,05**	**0,0002**	**12,61**	**0,0004**
fac. art. cost. C7	34	1	2,9	72	-	-	2,14	0,1437	0,15	0,6996
fac. art. cost. L1	19	-	-	55	-	-				
fac. art. sacral. acces. (Sa)	22	-	-	46	6	13,0	3,15	0,0761	1,73	0,1878

trait	Male			Female			χ2 test		Yates'correction	
	N	Incidence	%	N	Incidence	%	χ2	p	χ2	p
fac. art. sacr. acc. (Co)	15	2	13,3	59	7	11,9	0,02	0,8765	0,08	0,7742
fac. art. acces. cost. (Cl)	75	46	61,3	112	71	63,4	0,08	0,7755	0,02	0,8957
fac. art. acromialis	17	15	88,2	41	40	97,6	2,13	0,1444	0,65	0,4188
fac. art. acromialis absens	19	4	21,1	41	3	7,3	2,38	0,1232	1,23	0,2672
fac. art. proc. corac.	33	7	21,2	51	8	15,7	0,42	0,5184	0,13	0,7232
fac. art. carp. part. (Ra)	50	7	14	71	4	5,6	2,48	0,115	1,58	0,2094
fac. art. trochl. part. (Ul)	41	14	34,1	85	27	31,8	0,07	0,7892	-	0,9486
inc. radial. part. (Ul)	43	2	4,7	84	-	-	3,97	0,0463	1,54	0,2152
fac. lunata part. (Co)	53	-	-	139	-	-				
facies Poirieri (Fe)	**39**	**10**	**25,6**	**70**	**7**	**10**	**4,65**	**0,031**	**3,54**	**0,0598**
riding facet (Fe)	76	-	-	128	-	-				
facies Charlesi (Fe)	45	22	48,9	80	30	37,5	1,06	0,303	0,71	0,3992
fac. art. cond. media (Fe)	43	16	37,2	80	41	51,3	2,22	0,1365	1,69	0,1938
facies Charlesi+fac. art. cond. media (Fe)	52	38	73,1	99	71	71,7	0,03	0,8594	-	0,9889
fac. art. tib. acc. med.(Ti)	24	4	16,7	59	2	3,4	4,48	0,0342	2,72	0,0989
fac. art. tib. acc. lat. (Ti)	27	21	77,8	74	58	78,4	-	0,9484	0,04	0,8355
fac. art. tal. ant. et med. (Ca)	85	39	45,9	153	71	46,4	0,01	0,9382	0	0,9536
fac. art. tal. a. et m. com. (Ca)	88	48	54,5	155	88	56,8	0,11	0,7366	0,04	0,84
fac. art. tal. ant. bipart. (Ca)	87	1	1,1	167	-	-	1,93	0,1651	0,11	0,7395
fac. art. tal. med. bipart. (Ca)	91	-	-	169	-	-				
fac. art. tal. ant. absens (Ca)	86	1	1,2	163	6	3,7	1,31	0,253	0,55	0,4594
fac. art. calc. ant. et med. (Ta)	**81**	**20**	**24,7**	**160**	**20**	**12,5**	**5,77**	**0,0163**	**4,93**	**0,0265**
fac. art. calc. a. et m. com. (Ta)	83	64	77,1	159	138	86,8	3,71	0,0542	3,04	0,0813
fac. art. calc. ant. absens (Ta)	83	1	1,2	162	3	1,9	0,14	0,7053	0,02	0,8773
fac. art. med. tal. (Ta)	57	0	0	97	3	3,1	1,8	0,18	0,54	0,4611
proc. troch. tali lat. (Ta)	**57**	**8**	**14,0**	**119**	**6**	**5,0**	**4,26**	**0,0391**	**3,12**	**0,0775**
proc. troch. tali med.(Ta)	24	18	75	39	24	61,5	1,21	0,271	0,68	0,4091
for. supratroch.(Hu)	64	8	12,5	100	25	25	3,79	0,0515	3,06	0,0805
inc. fac. lunatae (Co)	90	21	23,3	128	31	24,2	0,02	0,88	-	0,9917
plate formation (Fe)	42	-	-	70	7	10	4,48	0,0343	2,94	0,0866
fossa Alleni (Fe)	56	4	7,1	88	1	1,1	3,68	0,055	2,11	0,1464
sulcus frontalis	85	28	32,9	127	53	41,7	1,67	0,1967	1,32	0,2515
for. et inc.supratr.	123	1	0,8	210	1	0,5	0,015	0,701	0,12	0,7257
for. et inc. frontalis	115	104	90,4	206	192	93,2	0,79	0,3747	0,45	0,5025
foramen frontale	112	23	20,5	193	53	27,5	1,82	0,1777	1,47	0,2261
incisura frontalis	108	84	77,8	186	147	79,0	0,06	0,8005	0,01	0,9161
for. et inc. suprorb.	120	7	5,8	210	4	1,9	3,66	0,0558	2,54	0,111
foramen supraorb.	121	7	5,8	213	4	1,9	3,7	0,0545	2,57	0,1087
incisura supraorb.	127	-	-	213	-	-				
for. nasale absens	62	2	3,2	77	10	13,0	4,15	0,0417	3	0,0831

trait	Male			Female			χ2 test		Yates'correction	
	N	Incidence	%	N	Incidence	%	χ2	p	χ2	p
for. zygomat. absens	107	9	8,4	170	11	6,5	0,37	0,5435	0,14	0,712
for. ethmoidale	49	48	98,0	84	82	97,6	0,02	0,8986	0,23	0,6327
can. opticus part.	48	-	-	91	1	1,1	0,53	0,4661	0,11	0,7441
for. infraorb. absens	68	-	-	129	-	-				
for. infraorb. part.	67	4	6,0	119	3	2,5	1,41	0,2354	0,62	0,4323
depr. bipar. circum.	69	-	-	223	-	-				
for. pariet. absens	81	47	58,0	154	90	58,4	0	0,9509	0,01	0,9382
for. pariet. inf.	78	-	-	119	-	-				
proc. pariet. sq. temp.	71	3	4,2	96	-	-	4,13	0,0421	2,08	0,149
for. squam. sup.	75	2	2,7	105	1	1,0	0,78	0,3758	0,09	0,7678
for. mastoid. intras.	67	29	43,3	84	33	39,3	0,25	0,6198	0,11	0,7417
for. mastoid. extras.	66	40	60,6	92	45	48,9	2,11	0,146	1,67	0,1963
for. tympan.	114	4	3,5	197	9	4,6	0,2	0,6527	0,02	0,876
for. marginale	111	4	3,6	195	11	5,6	0,63	0,4274	0,27	0,6043
for. occipitale	52	8	15,4	70	11	15,7	-	0,9604	0,04	0,8393
for. condylare	53	23	43,4	91	48	52,7	1,17	0,2791	0,83	0,363
can. condylaris	56	16	28,6	95	31	32,6	0,27	0,6027	0,11	0,7349
can. condyl. interm.	65	2	3,1	120	2	1,7	0,4	0,529	0,01	0,9202
for. hypogl. bipart.	***94***	***9***	***9,6***	***155***	***36***	***23,2***	***7,36***	***0,0067***	***6,47***	***0,011***
for. spin. incompl.	57	13	22,8	83	21	25,3	0,11	0,7353	0,02	0,8906
for. ovale incompl.	62	1	1,6	114	4	3,5	0,52	0,4696	0,06	0,8039
for.ovale et spin. confl.	70	-	-	142	1	0,7	0,5	0,4816	0,13	0,7174
for. Vesalii	69	11	15,9	125	15	12	0,6	0,4404	0,3	0,5813
for. ovale part.	71	1	1,4	132	1	0,8	0,2	0,6543	0,09	0,7663
for. mentale part.	130	-	-	235	-	-				
for. mentale absens	130	-	-	233	2	0,9	1,12	0,2895	0,1	0,7491
ponticulus mylohyoideus	99	5	5,1	171	7	4,1	0,14	0,7131	0	0,9511
sulc. myloh. absens	108	2	1,9	181	-	-	3,38	0,0662	1,22	0,2697
for. mandib. access.	93	1	1,1	147	4	2,7	0,76	0,3845	0,16	0,6848
for. pr. trans. part. C1-7	24	20	83,3	37	33	89,2	0,44	0,5081	0,07	0,7843
for. pr. trans. part. C1	43	1	2,3	55	-	-	1,29	0,2556	0,02	0,9013
for. pr. trans. part. C2	40	-	-	79	2	2,5	1,03	0,3102	0,07	0,7948
for. pr. trans. part. C3	34	-	-	61	-	-				
for. pr. trans. part. C4	36	1	2,8	67	4	6,0	0,52	0,4723	0,06	0,8118
for. pr. trans. part. C5	36	6	16,7	65	15	23,1	0,58	0,4471	0,25	0,614
for. pr. trans. part. C6	33	19	57,6	55	32	58,2	1,89	0,1688	1,37	0,241
for. pr. trans. part. C7	29	2	6,9	42	6	14,3	0,94	0,3331	0,34	0,5578
for. pr. trans. apart. C1-7	12	4	33,3	12	2	16,7	0,89	0,3458	0,22	0,6374
for. pr. trans. apart. C1	42	1	2,4	48	2	4,2	0,22	0,6378	0,01	0,9063
for. pr. trans. apart. C2	41	2	4,9	78	-	-	3,87	0,0492	1,48	0,2237
for. pr. trans. apart. C3	33	-	-	58	-	-				
for. pr. trans. apart. C4	35	-	-	66	-	-				

trait	Male			Female			χ2 test		Yates'correction	
	N	Incidence	%	N	Incidence	%	χ2	p	χ2	p
for. pr. trans. apart. C5	36	-	-	69	-	-				
for. pr. trans. apart. C6	33	-	-	53	-	-				
for. pr. trans. apart. C7	29	1	3,4	48	-	-	1,68	0,1953	0,07	0,7977
pont. os. sphenoid.	60	3	5	117	3	2,6	0,72	0,3966	0,17	0,6826
proc. pter.-spinos.	64	-	-	118	2	1,7	1,1	0,295	0,09	0,7621
proc. pter.-alaris	65	3	4,6	117	3	2,6	0,55	0,4577	0,1	0,757
ponticuli sellae	25	5	20	61	11	18,0	0,05	0,8314	0,01	0,9265
pont. clinoid medius	28	3	10,7	69	10	14,5	0,25	0,6206	0,03	0,8681
pont. carot.-clinoid.	30	2	6,7	69	1	1,4	1,94	0,164	0,57	0,4509
pont. interclinoid.	46	2	4,3	86	-	-	3,8	0,0514	1,44	0,2298
taenie interclinoid.	33	2	6,1	79	-	-	4,87	0,0273	2,03	0,1541
pont. atlantis	54	2	3,7	77	5	6,5	0,49	0,4846	0,09	0,7609
pont. atlantis lat.	60	-	-	90	2	2,2	1,35	0,2451	0,19	0,6629
pont. atlantis post.	60	2	3,3	88	5	5,7	2,81	0,0939	0,91	0,3403
for. suprascap.	58	-	-	94	7	7,4	4,53	0,0334	2,99	0,0837
spina trochlearis	74	13	17,6	153	26	17,0	0,01	0,9144	0,01	0,9361
tuberc. marginale	90	62	68,9	140	82	58,6	2,49	0,1145	2,07	0,1502
tuberc. zygomax.	71	16	22,5	137	29	21,2	0,05	0,8204	0	0,9605
torus palatinus	56	11	19,6	93	26	28,0	1,29	0,2552	0,89	0,3462
torus maxillaris	113	3	2,7	188	1	0,5	2,43	0,1194	1,08	0,2994
depres. suprameat.	**97**	**66**	**68,0**	**161**	**74**	**46,0**	**11,89**	**0,0006**	**11,02**	**0,0009**
spina suprameat.	**99**	**67**	**67,7**	**154**	**80**	**51,9**	**6,12****	**0,0133**	**5,49**	**0,0191**
torus acusticus	115	32	27,8	198	14	7,1	25***	-	23,37	-
torus occipitalis	**58**	**14**	**24,1**	**82**	**7**	**8,5**	**6,49**	**0,0109**	**5,32**	**0,0211**
proc. retromast.	87	6	6,9	122	5	4,1	0,8	0,3719	0,34	0,5627
tuberc. praecond.	**85**	**6**	**7,1**	**167**	**2**	**1,2**	**6,3**	**0,0121**	**4,53***	**0,0333**
tuberc. pharyng.	56	50	89,3	92	73	79,3	2,45	0,1176	1,79	0,1807
proc. paracond.	47	-	-	68	2	2,9	1,41	0,2356	0,21	0,6451
torus mandibul.	131	3	2,3	232	2	0,9	1,27	0,26	0,43	0,511
proc. supracond.	92	-	-	155	2	1,3	1,2	0,274	0,13	0,7191
for. supracond.	106	-	-	177	-	-				
troch. tertius	65	11	16,9	97	15	15,5	0,06	0,8041	0	0,9763
fossa pharyng.	53	16	30,2	86	25	29,1	0,02	0,8883	0	0,9594
linea nuchae supr.	57	24	42,1	75	41	54,7	2,04	0,1528	1,57	0,2098
fossa costaclavic.	**76**	**29**	**38,2**	**131**	**15**	**11,5**	**20,5**	**0**	**18,93**	**0**
fossa pector. maj.	**85**	**10**	**11,8**	**144**	**3**	**2,1**	**9,36**	**0,0022**	**7,64**	**0,0057**
fossa teres	91	2	2,2	147	2	1,4	0,24	0,6253	0	0,9757
fossa bicipitis	**50**	**12**	**24**	**85**	**4**	**4,7**	**11,22**	**0,0008**	**9,45**	**0,0021**
fossa hypotroch.	**104**	**15**	**14,4**	**182**	**8**	**4,4**	**9**	**0,0027**	**7,69**	**0,0059**
crista hypotroch.	79	34	43,0	108	45	41,7	0,04	0,8513	-	0,97

trait	Male			Female			χ2 test		Yates'correction	
	N	Incidence	%	N	Incidence	%	χ2	p	χ2	p
fossa gastrocn.	41	4	9,8	81	4	4,9	1,03	0,3099	0,39	0,5298
inc. musc. vasti lat. (Pa)	45	6	13,3	73	9	12,3	0,03	0,8736	0,02	0,9002
fossa. musc. vasti lat.	47	-	-	82	-	-				
fossa solei	69	7	10,1	116	11	9,5	0,02	0,8832	0,01	0,9128
crista solei	48	15	31,3	83	32	38,6	0,71	0,401	0,42	0,5152

Table 5. The average incidence of bilateral non-metric traits on the right and left side and verification of laterality differences using the chi-square test, Yates correction or McNemar´s test.
Explanatory notes: traits with a statistically significant difference in laterality are in bold type.

Trait	Right Side			Left Side			χ2 test		Yates' correction		McNemar test
	N	Inci-dence	%	N	Inci-dence	%	χ2	p	χ2	p	χ2
sut. parametop.	250	-	-	242	-	-					
oss. sut. coronalis	167	1	0,6	174	3	1,7	0,23	0,335	0,21	0,644	
ossiculum praefrontale	102	1	1,0	106	2	1,9	0,30	0,584	-	0,973	
lam. orbit. partita	24	-	-	21	1	4,8	1,12	0,291	-	0,965	
oss. zygom.part.	185	1	0,5	197	2	1,0	0,28	0,599	-	0,956	
fiss. zygom. transv.	159	6	3,8	160	7	4,4	0,07	0,786	-	0,991	
oss. sut. zygo-max.	146	2	1,4	167	4	2,4	0,44	0,509	0,06	0,805	
sut. infraorbitale	125	80	64	123	81	65,9	0,09	0,760	0,03	0,863	2,6
sutura incisiva	224	82	36,6	222	81	36,5	0	0,979	0,01	0,943	
oss. epiptericum	85	11	12,9	88	14	15,9	0,31	0,579	0,11	0,735	2
sut. frontotemp.	154	3	1,9	151	-	-	2,97	0,085	1,31	0,253	
proc. front. os.temp.	121	5	4,1	124	4	3,2	0,14	0,706	-	0,970	
proc. temp. os. front.	118	1	0,8	123	2	1,6	0,3	0,589	-	0,971	
proc. pariet. os. sphen.	92	18	19,6	89	9	10,1	3,18	0,074	2,48	0,115	
oss. inc. pariet.	124	6	4,8	133	14	10,5	2,89	0,089	2,15	0,142	2
os pariet. part.	218	-	-	220	-	-					
oss. sut. squam.	81	1	1,2	83	1	1,2	-	0,986	0,48	0,488	
sq. tempor. part.	152	2	1,3	151	1	0,7	0,33	0,565	0	0,995	
sut. squamom.	189	17	9,0	184	21	11,4	0,6	0,441	0,36	0,548	2
proc. mast. bipart.	165	4	2,4	157	5	3,2	0,17	0,679	0,01	0,940	
os. sut. lambdoid.	161	110	68,3	143	89	62,2	1,24	0,265	0,99	0,321	2,6
sut. mendosa	163	3	1,8	159	2	1,3	0,18	0,673	0	0,978	
oss. asterii	125	7	5,6	131	7	5,3	0,01	0,928	0,03	0,853	
oss. sut. occipit.	109	4	3,7	113	5	4,4	0,08	0,776	0	0,956	0,2
oss. acromii	54	-	-	55	1	1,8	0,99	0,320	0	0,993	
oss. coracoid.	76	-	-	60	-	-					
oss. styl. radii	59	-	-	52	-	-					
oss. styl. ulnae	38	-	-	25	-	-					
synost. acet. incompl. (co)	126	-	-	119	-	-					

Trait	Right Side			Left Side			χ2 test		Yates' correction		McNemar test
	N	Inci-dence	%	N	Inci-dence	%	χ2	p	χ2	p	χ2
oss. trigon. tali (Ta)	128	-	-	122	-	-					
fac. condyl. bipartita	110	5	4,5	105	2	1,9	1,19	0,276	0,5	0,480	
fac. art. sup. part. (C1)	101	20	19,8	102	17	16,7	0,33	0,563	0,16	0,692	0,7
fac. art. cost. C7	64	-	-	62	1	1,6	1,04	0,308	0	0,987	
fac. art. cost. L1	45	-	-	42	-	-					
fac. art. sacral. acces. (Sa)	34	4	11,8	32	2	6,3	0,61	0,436	0,12	0,726	
fac. art. sacr. acc. (Co)	60	6	10	56	3	5,4	0,87	0,350	0,34	0,557	
fac.art. acces. cost. (Cl)	121	70	57,9	107	53	49,5	1,58	0,209	1,26	0,261	**7,3**
fac. art. acromialis	28	27	96,4	30	28	93,3	0,28	0,595	0	0,951	
fac. art. acromialis absens	26	1	3,8	32	4	12,5	1,36	0,243	0,49	0,486	
fac. art. proc. corac.	52	11	21,2	34	6	17,6	0,16	0,690	0,01	0,903	
fac. art. carp. part. (Ra)	68	8	11,8	54	3	5,6	1,41	0,234	0,76	0,384	
fac. art. trochl. part. (Ul)	72	22	30,6	66	22	33,3	0,12	0,727	0,03	0,867	
inc. radial. part. (Ul)	72	2	2,8	67	-	-	1,89	0,169	0,44	0,508	
fac. lunata part. (Co)	126	-	-	118	-	-					
facies Poirieri (Fe)	69	9	13,0	72	8	11,1	0,12	0,725	0,01	0,926	
riding facet (Fe)	128	-	-	123	-	-					
facies Charlesi (Fe)	62	22	35,5	75	30	40	0,29	0,588	0,13	0,715	
fac. art. cond. media (Fe)	61	29	47,5	74	32	43,2	0,25	0,618	0,11	0,745	
facies Charlesi+fac. art. cond. media (Fe)	123	51	41,5	149	62	41,6	-	0,980	0,01	0,921	
patella multipartita	72	-	-	70	-	-					
fac.art.tib. acc.med. (Ti)	46	3	6,5	45	4	8,9	0,18	0,672	-	0,976	
fac. art. tib. acc. lat. (Ti)	61	50	82,0	51	37	72,5	1,42	0,233	0,93	0,335	
fac. art. tal. ant. et med. (Ca)	142	61	43,0	126	59	46,8	0,4	0,525	0,26	0,608	
fac. art. tal. a. et m. com. (Ca)	149	86	57,7	125	70	56,0	0,08	0,775	0,03	0,870	**4**
fac. art. tal. ant. bipart. (Ca)	149	-	-	137	1	0,7	1,09	0,296	-	0,966	
fac. art. tal. med. bipart. (Ca)	152	-	-	140	-	-					
fac. art. tal. ant. absens (Ca)	148	6	4,1	132	4	3,0	0,21	0,645	0,02	0,8901	
fac. art. calc. ant. et med. (Ta)	142	20	14,1	129	24	18,6	1,02	0,314	0,71	0,3993	
fac. art. calc. a. et m. com. (Ta)	146	124	84,9	126	103	81,7	0,5	0,481	0,29	0,5882	
fac. art. calc. ant. absens (Ta)	147	2	1,4	127	2	1,6	0,02	0,883	0,13	0,7207	
fac. art. med. tal. (Ta)	90	3	3,3	81	3	3,7	0,02	0,895	0,08	0,7758	
proc. troch. tali lat. (Ta)	97	7	7,2	97	7	7,2	-	1	0,08	0,7814	
proc. troch. tali med. (Ta)	12	-	-	9	-	-					
for. supratroch.	111	13	11,7	115	22	19,1	2,38	0,123	1,84	0,175	3,6
inc. fac. lunatae	121	30	24,8	107	24	22,4	0,18	0,675	0,07	0,793	
plate formation	67	5	7,5	73	6	8,2	0,03	0,868	0,02	0,882	
fossa Alleni	92	1	1,1	95	4	4,2	1,75	0,186	0,76	0,384	

Trait	Right Side			Left Side			$\chi 2$ test		Yates' correction		McNemar test
	N	Incidence	%	N	Incidence	%	$\chi 2$	p	$\chi 2$	p	$\chi 2$
sulcus frontalis	151	48	31,8	158	59	37,3	1,05	0,305	0,82	0,365	**8,2**
for. et inc. supratr.	237	1	0,4	247	1	0,4	-	0,977	0,46	0,497	
for. et inc. frontalis	222	204	91,9	231	208	90,0	0,47	0,493	0,27	0,602	0,4
foramen frontale	218	45	20,6	225	46	20,4	-	0,959	-	0,947	0,3
incisura frontalis	208	169	81,3	214	167	78,0	0,67	0,413	0,49	0,485	0,3
for. et inc. suprorb.	235	11	4,7	241	8	3,3	0,58	0,448	0,27	0,600	0,5
foramen supraorb.	241	11	4,6	245	6	2,4	1,61	0,205	1,04	0,307	1,7
incisura supraorb.	243	1	0,4	253	1	0,4	-	0,977	0,46	0,496	
for. nasale absens	88	10	11,4	77	4	5,2	2,01	0,156	1,3	0,255	
for. zygomat. absens	193	13	6,7	199	11	5,5	0,25	0,618	0,08	0,773	0,1
for. ethmoidale	85	82	96,5	84	82	97,6	0,19	0,660	-	0,989	
can. opticus part.	97	-	-	101	1	1,0	0,97	0,326	-	0,984	
for. infraorb. absens	154	-	-	149	-	-					
for. infraorb. part.	147	6	4,1	145	6	4,1	-	0,981	0,07	0,787	
depr. bipar. circum.	257	-	-	260	-	-					
for. pariet. absens	156	84	53,8	171	106	62,0	2,22	0,136	1,9	0,168	3,0
for. pariet. inf.	131	-	-	126	-	-					
proc. pariet. sq. temp.	111	1	0,9	107	2	1,9	0,38	0,540	-	0,975	
for. squam. sup.	124	3	2,4	119	1	0,8	0,94	0,334	0,21	0,644	
for. mastoid. intras.	91	36	39,6	85	32	37,6	0,07	0,795	0,01	0,916	0,7
for. mastoid. extras.	100	59	59,0	93	53	57,0	0,08	0,777	0,02	0,891	0,2
for. tympan.	218	22	10,1	214	19	8,9	0,19	0,667	0,07	0,790	0,4
for. marginale	223	13	5,8	225	6	2,7	2,92	0,088	2,16	0,142	0,8
for. condylare	122	66	54,1	110	60	54,5	-	0,946	-	0,949	**4,5**
can. condylaris	124	45	36,3	119	47	39,5	0,27	0,607	0,15	0,702	0,3
can. condyl. interm.	141	3	2,1	137	1	0,7	0,96	0,328	0,23	0,635	
for. hypogl. bipart.	182	24	13,2	177	31	17,5	2,41	0,120	1,98	0,159	0,0
for. spin. incompl.	87	21	24,1	98	20	20,4	0,37	0,542	0,19	0,665	0,1
for. ovale incompl.	124	2	1,6	133	3	2,3	0,14	0,709	0,01	0,937	
for. ovale et spin. confl.	128	2	1,6	134	2	1,5	-	0,963	0,21	0,647	
for. Vesalii	134	15	11,2	141	15	10,6	0,02	0,883	0	0,964	0,5
for.ovale part.	140	2	1,4	149	2	1,3	-	0,950	0,19	0,659	
for. mentale part.	272	1	0,4	273	1	0,4	-	0,998	0,5	0,480	
for. mentale absens	270	1	0,4	270	1	0,4	-	1	0,5	0,479	
pont. mylohyoid.	205	7	3,4	195	6	3,1	0,04	0,849	0,01	0,927	0,1
sulc. myloh. absens	213	2	0,9	207	2	1,0	-	0,977	0,22	0,636	
for. mandib. access.	179	13	7,3	170	8	4,7	1,01	0,315	0,61	0,436	
for. pr. trans. part. C1-7	42	38	90,5	35	31	88,6	0,07	0,785	0,01	0,919	
for. pr. trans. part. C1	51	1	2,0	66	-	-	1,31	0,253	0,02	0,897	
for. pr. trans. part. C2	79	-	-	81	2	2,5	1,98	0,160	0,48	0,488	

Trait	Right Side			Left Side			χ2 test		Yates' correction		McNemar test
	N	Inci-dence	%	N	Inci-dence	%	χ2	p	χ2	p	χ2
for. pr. trans. part. C3	63	-	-	60	-	-					
for. pr. trans. part. C4	65	3	4,6	66	2	3,0	0,22	0,636	-	0,986	
for. pr. trans. part. C5	64	17	26,6	62	14	22,6	0,27	0,604	0,1	0,755	0,4
for. pr. trans. part. C6	57	34	59,6	49	26	53,1	0,47	0,495	0,24	0,627	0,8
for. pr. trans. part. C7	41	4	9,8	38	6	15,8	0,65	0,420	0,22	0,640	
for. pr. trans. apart. C1-7	14	4	28,6	14	4	28,6	-	1,000	0,17	0,676	
for. pr. trans. apart. C1	49	3	6,1	60	2	3,3	0,48	0,489	0,05	0,816	
for. pr. trans. apart. C2	80	2	2,5	77	2	2,6	-	0,969	0,22	0,640	
for. pr. trans. apart. C3	60	-	-	56	-	-					
for. pr. trans. apart. C4	67	-	-	61	-	-					
for. pr. trans. apart. C5	65	-	-	64	-	-					
for. pr. trans. apart. C6	55	-	-	51	-	-					
for. pr. trans. apart. C7	45	-	-	41	1	2,4	1,11	0,292	-	0,963	
pont. os. sphenoid.	120	3	2,5	119	5	4,2	0,53	0,462	0,14	0,710	
proc. pter.-spinos.	121	1	0,8	120	2	1,7	0,35	0,556	-	0,994	
proc. pter.- alaris	123	3	2,4	123	4	3,3	0,15	0,701	-	1,000	
ponticuli sellae	86	11	12,8	83	12	14,5	0,1	0,752	0,1	0,927	
pont. clinoid medius	95	9	9,5	93	9	9,7	0	0,962	0,04	0,841	
pont. carot.-clinoid.	98	5	5,1	88	1	1,1	2,34	0,126	1,24	0,266	
pont. interclinoid.	115	2	1,7	116	1	0,9	0,35	0,556	-	0,994	
taenie interclinoid.	107	1	0,9	107	1	0,9	-	1,000	0,5	0,477	
pont. mylohyoid.	205	7	3,4	195	6	3,1	0,04	0,849	0,01	0,927	0,1
pont. atlantis	87	5	5,7	93	3	3,2	0,67	0,412	0,21	0,647	
pont. atlantis lat.	96	1	1,0	104	1	1,0	-	0,955	0,43	0,513	
pont. atlantis post.	96	5	5,2	100	3	3,0	0,61	0,435	0,18	0,675	
for. suprascap.	106	4	3,8	101	4	4,0	-	0,944	0,08	0,771	
spina trochlearis	167	30	18,0	162	21	13,0	1,57	0,212	1,21	0,271	**2,0**
tuberc. marginale	164	88	53,7	157	85	54,1	0,01	0,931	-	0,980	0,4
tuberc. zygomax.	137	29	21,2	138	27	19,6	0,11	0,741	0,03	0,857	
torus maxillaris	217	2	0,9	228	3	1,3	0,16	0,693	-	0,956	
depres. suprameat.	207	87	42,0	200	85	42,5	0,01	0,923	-	0,997	2,3
spina suprameat.	210	93	44,3	196	77	39,3	1,04	0,308	0,85	0,358	4,0
torus acusticus	238	29	12,2	238	33	13,9	0,3	0,586	0,17	0,683	3,0
proc. retromast.	27	2	7,4	24	2	8,3	0,02	0,902	0,01	0,903	
tuberc. praecond.	171	6	3,5	168	5	3,0	0,08	0,782	-	0,976	
proc. paracond.	68	-	-	68	2	2,9	2,03	0,154	0,21	0,476	
torus mandibul.	274	3	1,1	262	2	0,8	0,16	0,690	-	0,960	
proc. supracond.	160	1	0,6	162	2	1,2	0,32	0,569	-	0,991	
for. supracond.	183	-	-	182	-	-					
troch. tertius	99	15	15,2	105	13	12,4	0,33	0,566	0,14	0,711	0,1

Trait	Right Side			Left Side			χ2 test		Yates' correction		McNemar test
	N	Inci-dence	%	N	Inci-dence	%	χ2	p	χ2	p	χ2
linea nuchae supr.	96	37	38,5	95	38	40,0	0,04	0,837	0	0,954	
fossa costaclavic.	125	25	20	122	23	18,9	0,05	0,820	0	0,947	0,25
fossa pector. maj.	163	12	7,4	142	5	3,5	2,13	0,145	1,46	0,227	
fossa teres	162	5	3,1	150	7	4,7	0,53	0,488	0,19	0,667	
fossa bicipitis	90	10	11,1	82	11	13,4	0,21	0,645	0,05	0,820	
fossa hypotroch.	177	15	8,5	183	14	7,7	0,08	0,774	0,01	0,925	
crista hypotroch.	125	42	33,6	122	43	35,2	0,07	0,786	0,02	0,890	-
fossa gastrocn.	79	4	5,1	85	5	5,9	0,05	0,818	0,01	0,910	
inc.musc. vasti lat.	61	7	11,5	64	9	14,1	0,19	0,665	0,03	0,869	
fossa. musc. vasti lat.	69	-	-	69	-	-					
fossa solei	131	21	16,0	122	22	18,0	0,18	0,672	0,07	0,798	
crista solei	100	31	31	89	20	22,5	1,74	0,187	1,33	0,248	

Table 7. Incidence of bilateral non-metric traits and preference of a symmetrical/asymmetrical incidence. Explanatory notes: traits with a preference for a symmetrical incidence are in bold type, in the case of preference for an asymmetrical incidence they are in bold italics.

	Frequency				N	χ2 test		Yates´correction		McNemar test	
	2	21	22	1		χ2	p	χ2	p	A/D	B/C
oss.sut. coronalis		1	2	147	150	2,97	0,0848	1,31	0,2529	148,01	139,32
ossiculum praefrontale		1	1	95	97	1,98	0,1584	0,48	0,4863	95,01	89,25
fiss. zygom. transv.	4		1	104	109	1,76	0,1846	0,76	0,382	95,72	104,08
oss. sut. zygo-max.		1	2	111	114	2,96	0,853	1,3	0,2544	112,01	103,42
sut. infraorbitale	**52**	**4**	**10**	**30**	**96**	**16,64**	**0**	**15,49**	**0,0001**	**12,49**	**59,65**
sutura incisiva	**74**	**4**	**3**	**131**	**212**	**47,27**	**0**	**45,7**	**0**	**65,03**	**190,03**
oss. epiptericum	6	2	6	56	70	0,26	0,6103	0,05	0,8186	52,22	47,71
sut. frontotemp.		3		118	121	2,96	0,0852	1,3	0,2541	119,01	110,4
proc. front. os. temp.	2	3	2	85	92	1,24	0,2657	0,53	0,4667	84,27	76,25
proc. temp. os. front.	1		1	87	89	1	0,5	0,477	84,1	84,1	
proc. pariet. os. sphen.	7	5	1	54	67	0,07	0,7912	0	0,9795	47,04	49,32
oss. inc. pariet.	3	2	6	89	100	2,16	0,1421	1,34	0,2467	89,48	76,68
sut. squamom.	9	2	6	119	136	0,06	0,814	0	0,9883	109,49	112,01
proc. mast. bipart.	1	2	1	107	111	0,98	0,3216	0,24	0,6265	106,08	100,43
os. sut. lambdoid.	**66**	**20**	**11**	**42**	**139**	**9,44**	**0,0021**	**8,73**	**0,0031**	**25,29**	**67,35**
sut. mendosa	2			137	139	1,98	0,1588	0,49	0,4842	131,18	137,01
oss. asterii	4	2		99	105	0,65	0,4208	0,15	0,6958	91,74	97,23
oss. sut. occipit.	1	2	3	85	91	2,58	0,108	1,42	0,2332	86,1	75,26
fac. condyl. bipartita	2	3		82	87	0,19	0,6593	-	0,9899	79,28	76,54
fac. art. sup. part. (C1)	11	8	5	73	97	0,15	0,7001	0,03	0,866	66,9	62,63
fac. art. sacral. acces. (Sa)	1	3	1	25	30	1,67	0,1969	0,68	0,4097	25,29	18,38

	Frequency				N	χ2 test		Yates´correction		McNemar test	
	2	21	22	1		χ2	p	χ2	p	A/D	B/C
fac. art. sacr. acc. (Co)	1	3	1	42	47	1,71	0,1909	0,72	0,396	42,19	34,59
fac. art. acces. cost. (Cl)	**38**	**18**	**5**	**43**	**104**	**2,86**	**0,0908**	**2,39**	**0,1222**	**29,75**	**50,39**
fac. art. acromialis	**18**	**2**		**1**	**21**	**9,29**	**0,0023**	**7,65**	**0,0057**	**0,1 (,7488)**	**14,09 (,002)**
fac. art. acromialis absens	1		2	18	21	0,31	0,5769	-	0,9682	164,41	14,09
fac. art. proc. corac.	4	2		18	24	0,59	0,4411	0,11	0,7361	12,89 (,0003)	16,96
fac. art. carp. part. (Ra)	3	3		36	42	-	1	0,18	0,6726	32,09	32,09
fac. art. trochl. part.(Ul)	14	3	1	33	51	4,76	0,0292	3,7	0,0544	19,94	38,47
inc. radial. part. (Ul)		1		48	49	0,99	0,3197	0	0,9919	47,02	44,18
facies Poirieri (Fe)	5		1	41	47	2,51	0,1131	1,35	0,2448	32,33	42,19
facies Charlesi (Fe)	18		3	32	53	9,07	0,0026	7,68	0,0056	16,28	42,88
fac. art. cond. media (Fe)	**21**	**1**	**1**	**28**	**51**	**13,11**	**0,0003**	**11,47**	**0,0007**	**11,68**	**43,47**
facies Charlesi+fac. art. cond. media (Fe)	**40**		**3**	**60**	**103**	**26,93**	**0**	**25,2**	**0**	**26,88**	**92,46**
fac. art. tib. acc. med. (Ti)	1	1	1	24	27	0,32	0,5441	-	0,9751	22,32	19,86
fac. art. tib. acc. lat. (Ti)	24	2	2	7	35	10,65	0,0011	9,21	0,0024	1,69 (,1930)	23,08
fac. art. tal. ant. et med. (Ca)	**45**	**5**	**10**	**60**	**120**	**12,12**	**0,0005**	**11,13**	**0,0008**	**33,19**	**80,12**
fac. art. tal. a. et m. com. (Ca)	**60**	**12**	**4**	**50**	**126**	**19,93**	**0**	**18,77**	**0**	**22,72**	**83,67**
fac. art. tal. ant. bipart. (Ca)			1	123	124	1	0,3183	-	0,9968	122,01	119,07
fac. art. tal. ant. absens (Ca)	1	1	2	117	121	0,98	0,3213	0,24	0,6257	116,07	110,4
fac. art. calc. ant. et med.(Ta)	14	1	5	91	111	2,94	0,0865	2,19	0,1387	73,73	92,44
fac. art. calc. a. et m. com. (Ta)	**90**	**5**	**1**	**16**	**112**	**55,26**	**0**	**53,39**	**0**	**2,18**	**93,43**
fac. art. calc. ant.absens (Ta)	1	1		111	113	-	1	0,5	0,4776	108,08	108,08
fac. art. med. tal. (Ta)	2	1		55	58	0,32	0,5687	-	0,9882	50,42	53,15
proc. troch. tali lat.(Ta)	4	1	1	67	73	0,64	0,4235	0,15	0,7012	60,05	65,33
for. supratroch. (Hu)	7	2	8	72	89	0,48	0,4869	0,19	0,659	68,34	61,45
inc.fac. lunatae (Co)	**22**	**5**		**73**	**100**	**9,48**	**0,0021**	**8,26**	**0,0041**	**48,6**	**84,15**
plate formation (Fe)	4	1	1	42	48	0,63	0,4282	0,14	0,7104	35,56	40,5
sulcus frontalis	**30**	**5**	**19**	**76**	**130**	**0,55**	**0,4574**	**0,35**	**0,5528**	**61,26**	**71,59**
for. et inc.supratr.		1	1	209	211	1,99	0,1583	0,49	0,4826	209	203,12
for. et inc. frontalis	**170**	**12**	**9**	**11**	**202**	**84,2**	**0**	**82,55**	**0**	**2,58 (0,108)**	**145,29**
foramen frontale	22	18	15	149	204	1,94	0,1637	1,56	0,2116	144,96	121,94
incisura frontalis	**124**	**28**	**24**	**27**	**203**	**20,87**	**0**	**20,04**	**0**	**18,61**	**88,24**
for. et inc. suprorb.		***10***	***7***	***191***	***208***	***16,36***	***0,0001***	***14,42***	***0,0001***	***206***	***160,44***
foramen supraorb.		***10***	***5***	***196***	***211***	***14,5***	***0,0001***	***12,57***	***0,0004***	***209***	***168,25***
incisura supraorb.	1			210	211	1	0,3179	-	0,9981	206,04	209
for. nasale absens	3	5	1	69	78	0,95	0,3308	0,4	0,5289	67,6	60,01
for. zygomat. absens	2	4	5	136	147	4,3	0,0382	3,12	0,0775	139,17	120,31

	Frequency				N	χ2 test		Yates´correction		McNemar test	
	2	21	22	1		χ2	p	χ2	p	A/D	B/C
for. ethmoidale	**65**			**2**	**67**	**49**	**0**	**46,78**	**0**	**0,01 (0,9306)**	**65,01**
can. opticus part.			1	82	83	0,99	0,3188	-	0,9952	81,01	78,11
for. infraorb. part.	4	1	1	107	113	0,65	0,4203	0,15	0,6949	99,69	105,22
depr. bipar. circum.	1			234	235	1	0,3178	-	0,9983	230,04	233
for. pariet. absens	59	22	35	54	170	0,03	0,8726	-	0,9579	52,84	55,26
proc. pariet. sq. temp.	1		1	72	74	-	1	0,51	0,4766	69,12	69,12
for. squam. sup.	1	1		75	77	-	1	0,54	0,4767	72,12	72,12
for. mastoid. intras.	17	10	14	32	73	0,93	0,3337	0,62	0,4297	33,61	23,75
for. mastoid. extras.	24	13	11	27	75	-	1	0,03	0,8683	25,25	25,25
for. tympan.	10	6	4	160	180	-	1	0,05	0,8183	150,32	150,32
for. marginale	**2**	**7**	**4**	**174**	**187**	**6,02**	**0,0141**	**4,72**	**0,02898**	**179,13**	**154,67**
for. condylare	35	16	6	35	92	2,27	0,1319	1,84	0,1754	24,69	41,76
can. condylaris	25	9	7	57	98	1,64	0,2009	1,23	0,2682	42,15	57,55
can. condyl. interm.		2	1	110	113	2,96	0,0853	1,3	0,2545	111,01	102,42
for. hypogl. bipart.	***5***	***18***	***18***	***129***	***170***	***21,06***	***0***	***19,56***	***0***	***153,69***	***85,87***
for. spin. incompl.	10	6	5	45	66	0,04	0,8394	-	0,9743	39,8	37,87
for. ovale incompl.	1	1	1	92	95	0,33	0,5667	-	0,9928	90,09	87,26
for. ovale et spin. confl.	1	1		96	98	-	1	0,51	0,4773	93,09	93,09
for. Vesalii	9	3	5	89	106	0,05	0,8155	-	0,9851	80,14	82,54
for. ovale part.	2			106	108	1,98	0,1592	0,49	0,4856	100,23	106,01
for. mentale part.	1			252	253	1	0,3178	-	0,9984	248,04	251
for. mentale absens	1			250	251	1	0,3178	-	0,9984	246,04	249
sulc. myloh. absens	2			159	161	1,99	0,1586	0,49	0,4836	153,15	159,01
for. mandib. access.	4	5	2	115	126	0,78	0,3759	0,33	0,5637	112,62	104,69
for. pr. trans. part. C1-7	**20**	**3**	**1**	**3**	**27**	**7,71**	**0,0055**	**6,38**	**0,0115**	**,77 (0,3815)**	**15,61 (0,0001)**
for. pr. trans. part. C1		1		36	37	0,99	0,3205	-	0,9893	35,03	32,24
for. pr. trans. part. C2			2	64	66	1,96	0,1604	0,48	0,4894	64,02	58,37
for. pr. trans. part. C4			2	49	51	1,96	0,1613	0,47	0,4923	49,02	43,47
for. pr. trans. part. C5	9	6	4	32	51	0,04	0,8332	-	0,9687	28,02	26,23
for. pr. trans. part. C6	18	7	4	14	43	1,27	0,2601	0,83	0,3623	9,44 (0,0021)	17,8
for. pr. trans. part. C7	1		5	21	27	2,41	0,1205	1,26	0,2621	22,32	13,78
for. pr. trans. apart. C1-7	3	1		4	8	0,81	0,3687	0,11	0,736	1,45 (0,2278)	4 (0,0455)
for. pr. trans. apart. C1	2	1		32	35	0,32	0,5718	-	0,9807	27,68	30,25
for. pr. trans. apart. C2	1			62	63	0,99	0,3192	-	0,9937	58,14	61,02
pont. os. sphenoid.		2	2	90	94	3,92	0,0478	2,17	0,1405	92,01	80,83
proc. pter.-spinos.		1	1	91	93	1,98	0,1595	0,48	0,4866	91,01	85,26
proc. pter.- alaris		2	2	93	97	3,92	0,0477	2,18	0,1403	95,01	83,8
ponticuli sellae	9	2	2	66	79	1,78	0,1824	1,09	0,2961	54,1	65,98
pont. clinoid medius	6	3	2	79	90	0,09	0,7698	-	0,9857	71,76	74,27

	Frequency				N	χ2 test		Yates´correction		McNemar test	
	2	21	22	1		χ2	p	χ2	p	A/D	B/C
pont. carot.-clinoid.	1	2		83	86	0,33	0,5671	-	0,992	81,1	78,28
pont. interclinoid.	1			106	107	1	0,3184	-	0,9963	102,08	105,01
taenie interclinoid.	1			99	100	1	0,3197	-	0,996	95,09	98,01
pont. mylohyoid.	***1***	***5***	***4***	***146***	***156***	***6,21***	***0,0127***	***4,71***	***0,03***	***151,06***	***129,19***
pont. atlantis	2	2		70	74	-	1	0,26	0,6124	66,33	66,33
pont. atlantis lat.	1			82	83	0,99	0,3188	-	0,9952	78,11	81,01
pont. atlantis post.	2	3		78	83	0,19	0,6595	-	0,9894	75,29	72,57
for. suprascap.	1	2	2	71	76	2,57	0,1091	1,41	0,2357	71,12	60,49
spina trochlearis	13	12	6	111	142	0,73	0,3938	0,44	0,5069	105,7	94,56
tuberc. marginale	**56**	**6**	**4**	**44**	**110**	**25,32**	**0**	**23,91**	**0**	**16,92**	**81,68**
tuberc. zygomax.	**19**	**3**	**2**	**69**	**93**	**7,27**	**0,007**	**6,14**	**0,0132**	**47,58**	**77,23**
torus maxillaris	1	1		197	199	-	1	0,5	0,4784	194,04	194,04
depres. suprameat.	**59**	**14**	**7**	**91**	**171**	**14,75**	**0,0001**	**13,81**	**0,0002**	**53,57**	**115,63**
spina suprameat.	**59**	**12**	**4**	**94**	**169**	**20,4**	**0**	**19,25**	**0**	**52,11**	**124,89**
torus acusticus	21	3	9	176	209	2,28	0,1314	1,76	0,1843	152,04	173,83
proc. retromast.	2			5	7	1,78	0,1824	0,33	0,5677	1,78 (0,1824)	5,14 (0,0233)
tuberc. praecond.	3	2	2	153	160	0,14	0,7085	-	0,9935	149,3	146,46
proc. paracond.			1	51	52	0,99	0,3196	-	0,9924	50,02	47,17
torus mandibul.	2	1		246	249	0,33	0,5649	-	0,9972	241,1	244,04
proc. supracond.	1		1	132	134	0	1	0,5	0,4779	129,07	129,09
troch. tertius	8	5	4	64	81	0,05	0,8175	-	0,9807	58,25	56,01
linea nuchae supr.	**36**			**55**	**91**	**30,9**	**0**	**28,88**	**0**	**22,96**	**89,01**
fossa costaclavic.	13	9	7	78	107	0,27	0,6011	0,11	0,7452	72,07	65,85
fossa pector. maj.	5	5		109	119	-	1	0,1	0,7468	102,98	102,98
fossa teres	***1***	***3***	***4***	***117***	***125***	***4,36***	***0,0367***	***2,99***	***0,0837***	***120,07***	***103,7***
fossa bicipitis	4		2	49	55	0,63	0,4265	0,14	0,707	42,37	47,44
fossa hypotroch.	11	2	3	142	158	2,14	0,1433	1,46	0,2273	126,13	141,74
crista hypotroch.	**28**	**5**	**5**	**68**	**106**	**7,27**	**0,007**	**6,35**	**0,0118**	**44,25**	**77,8**
fossa gastrocn.	3		2	66	71	0,19	0,6603	-	0,9877	60,66	63,34
fossa Alleni (Fe)	1		1	61	63	-	1	0,51	0,476	58,14	58,14
inc. musc. vasti lat. (Pa)	4	1	4	29	38	0,1	0,7526	-	0,9702	25,93	23,81
fossa solei	15	3	4	71	93	2,61	0,1065	1,93	0,165	54,9	72,25
crista solei	15	5		47	67	4,37	0,0366	3,42	0,0643	31,72	51,68

Table 9. Comparison of the population group from the sub-castle (Kostelisko) and the castle on the basis of the measure of divergence. Traits in which both groups differed significantly statistically are in bold type.

traits	Mikulčice sub-castle			Mikulčice-castle			Measure of Divergence					
	N	Inci-dence	%	N	incid-Ince	%	MD	p=0,05	p=0,01	S^2 MD	Left Endpoint of 95 % Confidence Interval	Right Endpoint of 95 % Confidence Interval
sutura metopica	297	23	7,7	967	98	10,1	0,01122	0,01320	0,32209	0,00695	-0,15216	0,17460
oss. sut. coronalis	151	4	2,65	698	30	4,3	0,00884	0,02417	1,70000	0,02474	-0,29945	0,31714
oss. epiptericum	75	19	25,33	394	76	19,3	0,04366	0,04761	0,39474	0,00262	-0,05660	0,14393
sut. frontotemp.	121	3	2,48	457	12	2,6	-0,01026	0,03136	2,50000	0,02710	-0,33292	0,31241
oss. bregmatic.	217	1	0,5	719	1	0,1	0,00047	0,01800	12,00000	0,02036	-0,27921	0,28014
oss. sut. sagittal.	180	13	7,2	692	30	4,3	0,02540	0,02100	0,66154	0,00534	-0,11786	0,16866
oss. lambdae	99	20	20,2	702	125	17,8	-0,00172	0,03458	0,34800	0,00047	-0,04419	0,04074
oss. sut. lambdoid. abs.	175	42	24,0	658	281	42,7	**0,67669**	0,02170	0,16421	0,01098	0,47131	0,88208
fac. condyl. bipartita	87	5	5,7	476	10	2,1	0,06425	0,04079	1,80000	0,01016	-0,13330	0,26179
enlargement cap. femoris	53	19	35,8	406	210	51,7	0,18027	0,06399	0,34436	0,03531	-0,18805	0,54859
for. supraorbitale	213	17	8,0	894	198	22,1	**0,39614**	0,01744	0,38324	0,02227	0,10362	0,68866
incisura supraorbitalis	210	1	0,5	870	400	46,0	**5,59914**	0,01773	6,01500	0,16526	4,80235	6,39594
for. ethmoidale absens	101	2	2,0	241	4	1,7	-0,01268	0,04215	4,50000	0,03634	-0,38632	0,36096
for. infraorb. part.	116	8	6,9	512	1	0,2	**0,39164**	0,03172	6,75000	0,00088	0,33359	0,44969
for. hypogl. bipart.	179	50	27,9	546	15	2,7	**1,46881**	0,02225	0,52000	0,02647	1,14991	1,78771
for. ovale incompletum	96	3	3,1	620	33	5,3	0,01357	0,03609	2,18182	0,03657	-0,36125	0,38839
torus palatinus	221	44	19,9	605	147	24,3	0,02515	0,01853	0,17718	0,00188	-0,05982	0,11012
torus acusticus	217	41	18,9	882	33	3,7	**0,58716**	0,01723	0,32816	0,00322	0,47595	0,69836
tuberc. pharyng. absens	196	55	28,1	583	194	33,3	**0,03984**	0,02045	0,14002	0,00021	0,01120	0,06847
troch. tertius	84	20	23,8	668	194	29,0	0,03112	0,04021	0,33093	0,00216	-0,05991	0,12215
fossa pector. maj.	121	12	9,9	760	98	12,9	0,01116	0,02874	0,56122	0,01223	-0,20562	0,22793
fossa teres	128	11	8,6	748	111	14,8	0,07965	0,02745	0,59951	0,01898	-0,19039	0,34970
fossa pector. maj. et teres	128	2	1,6	755	40	5,3	0,08634	0,02741	3,15000	0,04272	-0,31877	0,49146
fossa hypotroch.	160	18	11,3	824	349	42,4	**1,81234**	0,02239	0,35053	0,05577	1,34946	2,27521
fossa solei	99	28	28,3	733	129	17,6	**0,17602**	0,03440	0,26080	0,00758	0,00535	0,34670

Table 11. Comparison of the population groups from the sub-castle (Kostelisko) and hinterland (Josefov) using the measure of divergence (on the basis of the same traits as in the case of the castle/sub-castle comparison). The traits in which both groups differed statistically significantly are in bold type.

traits	Mikulčice sub-castle			Mikulčice-castle			Measure of divergence					
	N	inci-dence	%	N	inci-dence	%	MD	p=0,05	p=0,01	S 2 MD	Left Endpoint of 95 % Confidence Interval l	Right Endpoint of 95 % Confidence Interval
sutura metopica	297	23	7,7	117	12	10,3	0,00499	0,03574	0,07148	0,01920	-0,26660	0,27658
oss. sut. coronalis	151	4	2,65	86	11	12,8	0,33697	0,05475	0,10950	0,10640	-0,30237	0,97630
oss. epiptericum	75	19	25,33	54	18	33,3	0,07508	0,09556	0,19111	0,00827	-0,10317	0,25332
sut. frontotemp.	121	3	2,48	51	1	2,0	-0,02506	0,08362	0,16723	0,06502	-0,52484	0,47471
oss. bregmatic.	217	1	0,5	93	-	-	-0,00890	0,04608	0,09217	0,05242	-0,45766	0,43987
oss. sut. sagittal.	180	13	7,2	103	10	9,7	0,00242	0,04579	0,09159	0,02659	-0,31716	0,32201
oss. lambdae	99	20	20,2	87	13	14,9	0,02725	0,06479	0,12957	0,00097	-0,03369	0,08818
oss. sut. lambdoid. abs.	175	42	24,0	89	44	49,4	**1,93941**	0,05085	0,10170	0,07074	1,41810	2,46073
fac. condyl. bipartita	87	5	5,7	43	3	7,0	-0,02913	0,10425	0,20850	0,06567	-0,53139	0,47314
enlargement cap. femoris	53	19	35,8	53	5	9,4	**1,21666**	0,11321	0,22642	0,11440	0,55373	1,87959
for. et inc. suprorb.	210	19	9,0	98	4	4,1	0,07384	0,04490	0,08980	0,00509	-0,06606	0,21373
for. ethmoidale absens	101	2	2,0	39	2	5,1	0,02746	0,10663	0,21325	0,14566	-0,72058	0,77550
for. infraorb. absens	115	-	-	80	2	2,5	0,10934	0,06359	0,12717	0,14482	-0,63655	0,85524
for. condylaris absens	126	35	27,8	49	7	14,3	0,27857	0,08503	0,17007	0,02675	-0,04201	0,59915
for. hypogl. bipart.	179	50	27,9	52	13	25,0	-0,01089	0,07445	0,14890	0,00400	-0,13480	0,11301
proc. marginalis absens	161	44	27,3	50	10	20,0	0,06081	0,07863	0,15727	0,03860	-0,32427	0,44590
torus palatinus	221	44	19,9	71	1	1,4	**1,04229**	0,05583	0,11166	0,02602	0,72610	1,35848
torus acusticus	217	41	18,9	75	3	4,0	**0,54606**	0,05382	0,10765	0,00979	0,35208	0,74004
tuberc. pharyng. absens	196	55	28,1	56	19	33,9	0,03658	0,06888	0,13776	0,00174	-0,04513	0,11828
troch. tertius	84	20	23,8	39	4	10,3	0,30234	0,11264	0,22527	0,02431	-0,00327	0,60796
linea nuchae supr.	94	39	41,5	81	21	25,9	0,44351	0,06895	0,13790	0,09167	-0,14992	1,03693
fossa pector. maj.	121	12	9,9	64	13	20,3	0,18771	0,07167	0,14334	0,05990	-0,29200	0,66743
fossa teres	128	11	8,6	62	8	12,9	0,02058	0,07182	0,14365	0,04229	-0,38250	0,42366
fossa hypotroch.	160	18	11,3	66	24	36,4	**1,08741**	0,06420	0,12841	0,11534	0,42176	1,75305
fossa solei	99	28	28,3	67	14	20,9	0,06318	0,07508	0,15016	0,01046	-0,13732	0,26368

Table 13. Comparison of the population groups from the castle and hinterland (Josefov) using the measure of divergence. The traits in which both groups differed statistically significantly are in bold type.

traits	Mikulčice sub-castle			Mikulčice-castle			Measure of Divergence					
	N	Inci-dence	%	N	Inci-dence	%	MD	p=0,05	p=0,01	S^2 MD	Left Endpoint of 95 % Confidence Interval l	Right Endpoint of 95 % Confidence Interval l
sutura metopica	967	98	10,1	117	12	10,3	-0,00956	0,02874	0,05749	0,00806	-0,18549	0,16638
oss. sut. coronalis	698	30	4,30	86	11	12,8	0,20410	0,03918	0,07836	0,05466	-0,25413	0,66232
oss. epiptericum	394	76	19,3	54	18	33,3	0,30498	0,06317	0,12634	0,02791	-0,02244	0,63241
sut. frontotemp.	457	12	2,63	51	1	2,0	-0,01731	0,06539	0,13078	0,04801	-0,44676	0,41215
oss. bregmatic.	719	1	0,1	93	-	-	-0,01214	0,03643	0,07286	0,05215	-0,45974	0,43545
oss. sut. sagittal.	692	30	4,3	103	10	9,7	0,08682	0,03346	0,06692	0,03708	-0,29062	0,46426
oss. lambdae	702	125	17,8	87	13	14,9	0,00197	0,03876	0,07751	0,00108	-0,06246	0,06639
oss. sut. lambdoid. abs.	658	281	42,7	89	44	49,4	**0,31626**	0,03827	0,07653	0,00149	0,24068	0,39185
fac. condyl. bipartita	476	10	2,1	43	3	7,0	0,09996	0,07607	0,15214	0,11722	-0,57110	0,77102
for. ethmoidale abs.	241	4	1,7	39	2	5,1	0,05315	0,08937	0,17874	0,13458	-0,66588	0,77219
for. infraorb. abs.	512	1	0,2	80	2	2,5	0,15046	0,04336	0,08672	0,10834	-0,49466	0,79559
can. condylaris abs.	545	477	87,5	55	30	54,5	**2,17631**	0,06005	0,12010	0,16190	1,38767	2,96494
for. hypogl. bipart.	546	15	2,7	52	13	25,0	**1,18235**	0,06319	0,12637	0,20366	0,29783	2,06687
torus palatinus	605	147	24,3	71	1	1,4	**1,44111**	0,04721	0,09442	0,04425	1,02883	1,85340
torus acusticus	882	33	3,7	75	3	4,0	-0,01411	0,04340	0,08680	0,03141	-0,36149	0,33328
tuberc. pharyng. abs.	583	194	33,3	56	19	33,9	-0,01879	0,05872	0,11743	0,00453	-0,15068	0,11310
troch. tertius	668	194	29,0	39	4	10,3	**0,60330**	0,08141	0,16283	0,05118	0,15988	1,04672
fossa pector. maj.	760	98	12,9	64	13	20,3	0,08292	0,05082	0,10164	0,02341	-0,21698	0,38281
fossa teres	748	111	14,8	62	8	12,9	-0,00990	0,05240	0,10480	0,00444	-0,14046	0,12066
fossa hypotroch.	824	349	42,4	66	24	36,4	0,07125	0,04910	0,09819	0,03752	-0,30840	0,45090
fossa solei	733	129	17,6	67	14	20,9	0,00221	0,04887	0,09774	0,00675	-0,15885	0,16326

Estimation of Biologically Related Groups of Individuals at the Mikulčice-Kostelisko Burial Site on the Basis of Morphological Similarities, Topography of the Burial Site and Archaeological Data

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The goal of this paper was to verify, whether the incidence of non-metric traits at the Mikulčice-Kostelisko (sub-castle) burial site differs in individuals with rich and poor grave equipment i.e. whether it differs between two, socially quite probably dissimilar groups. We then compared the morphological similarity of individuals in relation to the topography of the burial site. We divided the individuals on the basis of the character of grave inventory in accordance with two classifications (Hrubý 1955; Stloukal 1970). Comparison of the smaller group of individuals from graves with rich equipment defined according to Hrubý's criteria yielded more favourable results, as it showed statistically significant differences in the incidence of several traits, which may represent "ancestral" hereditary non-metric traits. Most of the differences, though, were due to sexual dimorphism. Finally, we placed the morphological similarity and grave equipment in relation to the topography of the burial site, and we tried to find groups of individuals in whom a biological relatedness could be expected. Some of the comparisons suggested certain ties. We must keep in mind, though, that with the aid of non-metric morphological traits we can only determine that the probability of biological relatedness between certain individuals is greater/smaller than between other individuals.

Key words: Early Medieval period – Mikulčice – non-metric traits – socio-economic status – grave equipments – topography of burial ground

1. Introduction

If we visit a cemetery today, walking through its alleys and lanes we pass tombs, where usually biologically related persons are buried. The tendency to concentrate biologically related individuals near each other may be presumed to have taken place in the past as well, that is in the case of burial sites dating from the Great Moravian period. Thus, it would not be surprising if, for example, members of one clan were buried at the same burial site. If one considers, for example, that the settlement agglomeration of Mikulčice was inhabited in the second half of the ninth century by one to two thousand persons (e.g. Stloukal/Vyhnánek 1976), then it is very probable that a number of biologically related individuals is buried at the Mikulčice burial site. For example, the smaller burial site at the IVth Mikulčice church is often cited as the possible ancestral burial ground of the ruling class (e.g. Poulík 1975). The biological relatedness between members

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of the ruling class is very likely. The burials of biologically related individuals may thus be logically expected also at the Kostelisko burial site. In view of its size, character and grave findings, it is presumed that artisans, peasants, as well as members of the military retinue or persons of a socially higher rank were buried there, i.e. that this is a burial site of "general" character. This, after all, has also been suggested by the results of the palaeo-demographic analysis of the burial site (Velemínský et al. 2005).

Naturally, the means and possibilities of demonstrating the biological relatedness of individuals in prehistoric burial sites are quite limited. The absence of soft tissue precludes the application of current routine forensic medicine genetic methods. Partly, one may conduct the morphological or metric comparison of the skeletons, or one may attempt to demonstrate relatedness genetically, on the basis of bone DNA. In the first case, which we applied in this work, so-called non-metric morphological traits are most frequently used.

Generally, these involve slight anatomical deviations from the common bone structure, which have a certain degree of heritability (the common state most often refers to the most frequently recorded situations within the relevant human population). Traits are predominantly determined genetically. External (environmental) and internal (physiological) factors affect their incidence, but their contribution is not deemed to be decisive. The validity of the aforementioned is only presumed for a number of traits, but it has not been verified. This mainly relates to traits localised on the post-cranial parts of the skeleton. Although the genetic basis also plays a role, the relationship between the incidence of such traits and other, "non-genetic" factors (the development of the muscle apparatus, skeleton robustness, sex) is apparent in a number of cases. Specific examples of this are traits in the region of ligament/muscle attachments.

The morphological resemblance of individuals naturally only indicates a probability, but does not definitely establish biological relatedness.

The goal of this paper was to verify, whether the incidence of non-metric traits differs in graves with rich and poor grave equipment, i.e. whether it differs in two most probably socially different groups. We compared the morphological similarity of individuals also in relation to the topography of the burial site, which may also indicate the biological relatedness of individuals.

2. Material and methods

The burial site at Kostelisko, where 425 graves have been uncovered, is the largest burial site in the sub-castle area of the Mikulčice settlement agglomeration. The burial site has not been dug completely. The skeletal remains of around 456 individuals have been found in the graves. Based on the grave equipment, it may be presumed that higher echelons of society were buried there. From a demographic aspect, female and non-adult individuals are more frequently represented (Velemínský et al. 2005). Based on the incidence of non-metric traits, we compared two population groups with a defined grave equipment character. We divided the individuals on the basis of the character of grave inventory in accordance with two classifications. The first study we took as our basis was that of Hrubý (1955), which defined five categories. We included in the group with rich grave equipment those individuals who met the criteria of the first and second group according to Hrubý's classification. We also applied Stloukal's (1970) more general proposal, designated for osteological purposes, and which differentiates only two groups- graves with rich equipment and graves with poor equipment.

The classification according to Hrubý (1955)

1. graves with very rich equipment – with a sword, two or more pairs of gold earrings
2. rich graves – axes , spurs, a pair of gold earrings or several pairs of gold-plated earrings, vessels of a Byzantine character
3. graves with average posthumous equipment – with a knife, razor, sharpening steel, studs, necklaces, several pairs of silver or bronze

earrings, pails etc

4. poor graves – with a knife, one pair of silver or bronze earrings, a stud, bead or cup
5. graves without equipment

The classification according to Stloukal (1970)

1. graves with swords, spurs, axes; graves with gold, silver or bronze objects
2. graves without equipment; graves with knives or other fine objects from gold, ceramics or glass.

Fifty graves met the criteria for rich graves according to Hrubý's classification (group 1-2), and 134 individuals met the criteria using Stloukal's more general proposal.

We evaluated the incidence of roughly one hundred fifty non-metric traits on the skeletons, of which ninety were located on the skulls and sixty-two on the bones of the post-cranial skeleton. Our methodology was based on the work of Finnegan/Faust (1974), Reinhard /Rösing (1985), Czartnetzki et al. (1985), Hauser/DeStefano (1989) and Velemínský (1999). For purposes of subsequent evaluation, we divided the traits into several groups, according to their character or function. This distribution cannot be taken in complete strictness, as the classification of certain traits is problematic. These traits related to:

A – Skull sutures (Epigenetic variants).

B – Presence, absence or nature of foramens – vascular outlets or nerve routes.

C – Presence, absence or nature of joint facets and their alterations.

D – Disorders of ossification, non-junction of the ossification centres or their absence.

Ea – Hyperostotic activity, with the presence of osseous tori, tubercles, spines or bridges.

Eb – Changes in the region of muscle/ligament attachments – loss of bone tissue or fibrous ossification resulting in the genesis of osseous prominences (enthesopathies). This is associated with marked long-term stress acting upon relevant muscle groups. According to Ossenberg (1977) these are termed hypostotic traits.

To verify the differences in the incidence of non-metric traits among individuals with rich and poor grave equipment, we used tests that compare nominal traits in independent selections (e.g. Zvára 1999, Statistica (STATISTICA 5.0 for Windows, StatSoft, Inc.) and the so-called Measure of Divergence (MD) or Mean Measure of Divergence (MMD) (e.g. Sjøvold 1973). This basically entails determining the degree of dissimilitude of the probabilities measured (Zvára 1999). The starting premise, null hypothesis (H_0), was that the relevant trait occurs with the same probability in both groups. We used the aforementioned tests only to determine whether a concurrence in the incidence does or does not exist, not to determine how great the eventual difference (dependence) of trait frequency is in the groups compared.

We used cluster analysis to find individuals who show greater concurrence in the incidence of non-metric traits. The principle of this method is the attempt to separate within a group of objects those that are in some way close, similar. In the case of the Kostelisko burial site, we attempted to identify individuals/groups (clusters) of individuals among whom a more significant degree of concurrence of non-metric traits exists. Cluster analysis ranks among the subjective methods of multivariate analysis. It searches for similarities between evaluated objects and clusters together similar elements, while it classifies mutually different elements into various groups (Havránek 1983). It does not take into consideration the possible random character of data, which is why it is not considered to be a statistical method (Zvára 1999). We based our evaluations on the procedure described in the work of Unzeitigová (2000). A matrix was created for each pair of skeletons, where the columns represented traits and the rows represented individuals, i.e. the matrix consisted of twos (presence of trait) and ones (absence of trait). We then determined the number of cases, where the incidence of a given trait differed in the group of compared individuals. The distance between individuals was taken as the percentage of such "divergences".

This calculation does not include situations, whereby the trait is absent in both compared individuals. In the case of traits with a low population incidence, the predictive value regarding the similarity of skeletons is nearly zero. This way, only the mutual distances of all individuals are determined. The distance between two groups (clusters) of individuals was defined as the Euclidean average of the distances between all individuals of both these groups (clusters) – weighted pair-group centroid (median) – or as the distance between the most distant elements-individuals (complete linkage). The graphical output of such an evaluation is the dendogram.

The algorithm of cluster analysis is as follows: first, the mutual distances between all individuals are calculated. Next, the two closest individuals are separated and classified into one group. Then, the new distances between this group and the remaining individuals are calculated. In the next step, the closest individuals (or group) are again separated, etc. This sequence is repeated until all individuals have been classified (Unzeitigová 2000).

A completed matrix is a pre-condition for the calculation itself. If we wish to compare, for example, twenty individuals on the basis of ten traits, only those individuals in whom all ten traits can be evaluated can be compared. The individual with a single, non-evaluable trait must be excluded from the comparison. The presence of missing values pre-conditions the reduction in the number of individuals compared or of the number of traits on who basis the given individuals are to be clustered.

We strove to conduct comparisons always in a group of traits with the same character or function.

3. Results and Discussion

The primary goal was to determine the incidence of selected non-metric morphological traits in the skeletal remains of individuals buried at Kostelisko and to determine the average population frequency of these traits. In the case of statistically significant dependence on sex, the given trait was excluded from the comparison, or this fact was taken into consideration when interpreting results (see Velemínský et al. this book, pp. 265-304)

Further calculations focused on predicting individuals whom we could presume to be biologically related. We focused only on the group of graves with rich grave equipment. In the pagan or early Christian era, the grave inventory may be seen as a source of information regarding the social rank of an individual. Moreover, it may be presumed that individuals of higher rank were often biologically related. If we also take into consideration the size of the Mikulčice settlement agglomeration and the estimated number of its inhabitants, we may expect that within the group of graves with rich equipment at the Kostelisko burial site there is a higher representation of biologically related skeletons. Thus, on the basis of the incidence of non-metric traits, we first compared the group of individuals from rich graves with the remaining population of Kostelisko. We worked with two groups of rich graves. The first, more specific, was selected according to Hrubý's criteria (1955) (group I) and the second, less definite, was selected according to Stloukal's criteria (1970) (group II). We attempted to determine, whether certain non-metric traits have a statistically different incidence in the group of individuals with rich grave equipment. If the premises detailed above hold, such traits could be considered, with some exaggeration, to be ancestral traits. We used the measure of divergence, mean measure of divergence and the Chi-square test to verify this.

In order to identify individuals at the burial site in whom biological relatedness could not be excluded, we basically took the following two approaches:

- we selected individuals with "ancestral" non-metric traits and compared the position of their graves. We thus started from the premise that the graves of blood-relatives could neighbor on each other or could be located in the same section of the burial site

- we selected individuals with non-metric traits whose population frequency within the group of rich graves was less than twenty percent, and we compared the mutual position of the graves of individuals with such traits, i.e. we again focused on the topography of the graves
- we compared individuals on the basis of groups of non-metric morphological traits of similar character with the aid of cluster analysis. This comparison was limited by the missing values, i.e. those cases where the given trait could not be evaluated due to damage or absence of the relevant part of the bone.

3.1 Non-metric traits in individuals with rich grave equipment

We tested the concurrence in the incidence of non-metric traits between individuals from "rich" and "poor" graves with the aid of the four-field table, Yates' modification of the chi-square test and by calculating the measure of divergence. We worked with two groups of individuals with a rich grave inventory – group I (Hrubý 1955) and group II (Stloukal 1970).

3.1.1 Graves with rich grave equipment I

We first focused on the smaller group of individuals with rich grave equipment, selected using the criteria of Hrubý (1955). For each non-metric trait, we calculated its average incidence in the given group and in the rest of the burial site. In the case of bilateral traits, we compared their frequency expressed as the average for a non-specific side. We then verified the differences in incidence between both groups with the aid of appropriate tests.

Table 1 lists the traits with a statistically significant different incidence in both groups when using the chi-square test. Statistically significant differences were demonstrated in the case of twenty two traits. The different incidence, though, was most often probably due to the demographic structure of the group of rich skeletons with male predominance, or more specifically to the sexual dimorphism in the incidence of non-metric traits at Kostelisko. In view of the poor state of skeleton preservation, the number of evaluated cases was usually low.

In individuals with graves with a rich inventory, it was often noted that two isolated facets participated in the communication between the calcaneus and talus (*facies articularis calcanea anterior et medialis*), while in the remaining population of Kostelisko these facets were more often fused (*facies articularis calcanea anterior et media communis*). A similar situation was found in the case of the analogical articular facets on the calcaneus – *facies articularis talaris anterior et media* (more frequent incidence in rich graves statistically not demonstrated) and the *facies articularis talaris anterior et media communis* (more frequent in graves with poor equipment). Yet, if we look at the demographic structure of the group of individuals with rich grave equipment (I), where males

Table 1. Non-metric traits (NMT) with a statistically different incidence in groups of individuals with rich grave equipment I (Hrubý 1955) at the Mikulčice-Kostelisko burial site.
Explanatory notes: attained level of significance of the chi-square test: p=0.5 ….. *; p=0.01 ….. **; p=0.001 ….. ***

More Frequently Incidence at the Group with Rich Grave Equipment I			Less Frequently Incidence at the Group with Rich Grave Equipment I
sutura supranasalis*	proc. pariet. sq.temp.*	torus maxillaris**	fac. art. tal. ant. et med. com.*
fac. art. trochl. partita*	for. Vesalii***	spina suprameatica*	fac. art. calc. ant. et med. com.**
facies Charles*	pont.interclinoideus*	torus acusticus*	for. hypogl. part.*
fac. art. calc. ant. et med.*	taenie interclinoidea**	torus mandibularis***	for. spin. incompl.**
fossa Alleni*	pont. atlantis*	fossa costoclavicularis***	tub. zygomaxillare*
for. infraorbitale part.****	pont. atlantis post.**		sutura incisiva

Table 2. Comparison of the incidence of non-metric traits in individuals from graves with rich equipment I (Hrubý 1955) and the other individuals buried at Kostelisko with the aid of the measure of divergence.
Explanatory notes: statistically significant values at p=0.05 are in bold italics; statistically significant values at p=0.05 and p=0.01 according to Sjovold´s criteria (1973) are in italics

trait	Mikulčice-Kostelisko - the Graves with Rich Goods			Mikulčice-Kostelisko - the Graves with Poor Goods			Measure of Divergence					
	N	Incidence	%	N	Incidence	%	MD	p=0,05	p=0,01	S^2 MD	Left Endpoint of 95% Confidence Interval	Right Endpoint of 95% Confidence Interval
sutura supranasalis absens	26	5	19,2	190	79	41,6	*0,19996*	0,13117	0,26235	0,12079	-0,48124	0,88116
sutura incisiva	48	3	6,3	398	160	40,2	*0,73039*	0,07004	0,14008	0,17566	-0,09109	1,55187
os epiptericum	27	1	3,7	146	24	16,4	*0,15647*	0,13166	0,26332	0,23737	-0,79845	1,11139
proc.pariet. os. sphen.	28	7	25,0	153	20	13	0,05221	0,12675	0,25350	0,00752	-0,11779	0,22220
f.ac. Charles+f.ac. cond. media	18	15	83,3	254	98	38,6	*0,86231*	0,17848	0,35696	0,34685	-0,29200	2,01663
fac. art. tal.ant.et med. (Ta)	29	9	31,0	242	35	14,5	*0,12259*	0,11584	0,23169	0,00299	0,01534	0,22984
fac. art.t al. ant.et med. com absens (Ta)	30	10	33,3	242	35	14,5	***0,16568***	0,11240	0,22479	0,00373	0,04600	0,28536
fossa Alleni	11	2	18,2	176	3	1,7	***0,2868***	0,28977	0,57955	0,01962	0,01220	0,56133
incisura supraorbitalis	57	2	3,5	439	-	-	*0,12220*	0,05947	0,11893	0,02725	-0,20136	0,44576
for.infraorbitale partitum	30	5	16,7	262	7	2,7	***0,2257***	0,11145	0,22290	0,00626	0,07062	0,38078
proc.pariet. sq.tempor.	23	2	8,7	195	1	0,5	*0,1587*	0,14582	0,29164	0,03069	-0,18465	0,50207
can. tympanicum	44	1	2,3	388	40	10,3	*0,09795*	0,07591	0,15183	0,13397	-0,61945	0,81534
for. hypogl. bipart.	39	1	2,6	320	54	16,9	*0,24686*	0,08630	0,17260	0,18275	-0,59101	1,08474
for. spin. incompletum	22	-	-	163	41	25,2	*1,0525*	0,15477	0,30954	0,71441	-0,60419	2,70911
for. Vesalii	22	7	31,8	253	23	9,1	***0,29407***	0,14822	0,29644	0,00940	0,10401	0,48414
ponticuli sellae	15	4	26,7	154	19	12,3	*0,06187*	0,21948	0,43896	0,01274	-0,15939	0,28313
ponticuli atlantis posterior	26	4	15,4	170	4	2,4	***0,20377***	0,13303	0,26606	0,01023	0,00548	0,40206
torus maxillaris	51	3	5,9	394	2	0,5	*0,09850*	0,06644	0,13288	0,02481	-0,21023	0,40723
torus acusticus	46	11	23,9	430	51	11,9	*0,07752*	0,07219	0,14439	0,00371	-0,04182	0,19687

trait	Mikulčice-Kostelisko - the Graves with Rich Goods			Mikulčice-Kostelisko - the Graves with Poor Goods			Measure of Divergence					
	N	Inci-dence	%	N	Inci-dence	%	MD	p=0,05	p=0,01	S^2 MD	Left Endpoint of 95% Confi-dence Interval	Right Endpoint of 95% Confi-dence Interval
torus mandibularis	57	3	5,3	479	2	0,4	*0,09168*	0,05889	0,11779	0,02431	-0,21389	0,39724
fossa costaclavic.	28	13	46,4	219	35	16,0	***0,41774***	0,12084	0,24168	0,03276	0,06299	0,77249
fossa pector.maj.	24	-	-	281	17	6,0	*0,20181*	0,13568	0,27135	0,39085	-1,02354	1,42716
fossa teres	28	-	-	284	12	4,2	*0,13221*	0,11771	0,23541	0,31223	-0,96298	1,22741
fossa bicipitis	13	3	23	159	18	11,3	0,01656	0,24964	0,49927	0,02448	-0,29010	0,32322
fossa hypotroch.	33	3	9,1	327	26	8,0	-0,03169	0,10008	0,20017	0,05838	-0,50527	0,44188
crista hypotroch.	22	10	45,5	225	75	33,3	0,01200	0,14970	0,29939	0,00746	-0,15733	0,18133
fossa solei	21	2	9,5	232	41	17,7	0,00581	0,15579	0,31158	0,15090	-0,75556	0,76718

clearly predominate, and at the results of verification of the sexual dimorphism of the incidence of these traits at Kostelisko, it is quite probable that the differences between the rich and poor group were mainly due to the different representation of traits in both sexes. The different incidence in males and females may also explain the differences in the incidence of other traits, *sutura supranasalis, torus acusticus, spina suprameatica, fossa costoclavicularis, fossa bicipitis* and *foramen hypoglossalis partitus*. The demographic structure and sexual dimorphism to a certain extent affect the fact that traits of a hyperostotic character occur more frequently in individuals with rich graves, while traits of a hypostatic character occur more frequently in individuals from poor graves. Both groups differ, for example, in the incidence of all traits associated with sites of muscle attachments. Apart from the *fossa costoclavicularis*, the *fossa bicipitis, crista hypotrochanterica* and *crista solei* occur more often in the group of "rich" skeletons (this difference was not statistically proven). In poor graves, the *fossa pectoralis major, fossa teres, fossa solei, fossa gastrocnemica* and *linea nuchae suprema* are developed more often. The *fossa pectoralis major*, whose incidence at Kostelisko was shown to be statistically greater in men, was not found at all in the group of individuals from rich graves. A similar situation also applies in the case of the *fossa gastrocnemica.* Also, the *fossa teres*, which in Kostelisko showed more or less the same incidence in both sexes, did not occur in any skeleton from rich graves. The influence of the difference in incidence in both sexes may be also be ruled out in the case of the *tuberculum zygomaxillare, foramen Vesalii*, *ponticulus atlantis, facies articularis trochlearis partita* and more or less also of the *foramen infraorbitale partitum* and *torus mandibularis*. In view of their possible ancestral heredity within the group of individuals with a rich grave inventory, these six traits have the highest predicative value. The *fossa Alleni* was evaluable only in several individuals (11/2), which is why we do not consider the significant difference in its case to be conclusive.

Table 3. Comparison of the graves with rich equipment I (Hrubý 1955) with the other individuals buried at Kostelisko on the basis o the group of non-metric traits using the mean measure of divergence.
Explanatory notes: statistically significant values are in bold italics

Trait Group	MMD	S^2mmd	MDD-1,96 S^2mmd	MDD+1,96 S^2mmd
cranial sutures	0,28476	0,03383	-0,07577	0,64528
articular facets	***0,47912***	0,04147	0,08	0,87823
vessel and nervous foramina	***0,25795***	0,01948	0,01948	0,49642
hyperostotic traits	0,08923	0,00587	-0,06092	0,23939
areas of muscle/fibrous insertions	0,10778	0,01994	-0,16899	0,38455
Total	***0,21926***	0,00431	0,09056	0,34797

Table 4. Non-metric traits with statistically different incidence in individuals with rich equipment II (Stloukal 1970) and the remaining part of the burial site at Kostelisko.
The stars characterise the level of significance reached using the chi-square test: p=0.5 ….. *; p=0.01 ….. **; p=0.001 ….. ***

More Frequently Incidence at the Group with Rich Grave Equipment II			Less Frequently Incidence at the Group with Rich Grave Equipment II
proc. temp. os. front.*	facies Charlesi***	for.condylaris*	sutura incisoiva***
oss. sut. lambdoideae*	fac. art. tal. ant. et med.*	for. proc. trans. part. C1-7***	fac. art. tal. ant. et med. com.***
		crista solei*	for. hypogl. part.*
			fossa solei*

In the next step, we verified in both groups the difference in the incidence of traits, which were statistically significant when applying the chi-square test, by calculating the measure of divergence (MD). We also included in the calculation those traits, in which the chi-square test values were not statistically significant but exceeded the value of two. These results are listed in Table 2. A different incidence at the 5% level of significance was found in the case of the *facies articularis calcanea anterior et medialis, facies articularis calcanea anterior et media communis, fossa Alleni, foramen infraorbitale partitum, foramen Vesalii, ponticulus atlantis posterior* and *fossa costoclavicularis*. This means that the number of traits with a different incidence in both compared groups significantly decreased when using the MD. If we take into consideration sexual dimorphism, we may consider the existence of "ancestral traits" only in the case of the *foramen infraorbitale partitum*, *foramen Vesalii* and *ponticulus atlantis posterior*.

Table 3 then lists the values of the mean measure of divergence for the groups of non-metric traits of similar character. Both groups had a statistically proven different incidence of those traits involving vascular and nerve outlets and the character of articular surfaces. No difference was shown, though, in the incidence of traits associated with the sites of muscle insertions. The total MMD value was 224.5.

3.1.2 Graves with rich grave equipment II

We proceeded analogically in the case of the group of individuals with rich grave equipment, selected according to the criteria of Stloukal (1970). For each non-metric trait, we calculated its average incidence for this group and for the rest of the burial site, and we compared both values using the four-field table and Yates correction. The non-metric traits for which we demonstrated statistically significant differences are listed in Table 4.

In view of the situation in the case of the previous comparison, we took into consideration the difference in the incidence of each trait in both sexes. Sexual dimorphism most probably lay behind the determined statistically significant difference in the incidence of the *ossicula suturae lambdoidea*, *facies articularis talaris anterior et media communis* and *foramen hypoglossalis partitus*. The other traits may be associated with ancestral heredity within the group of individuals with a rich grave inventory. The *foramen processus transversi partitum* of cervical vertebrae was evaluated in a small number of individuals. The statistically most significant difference was shown in the incidence of the *sutura incisiva* and *facies Charlesi.*

The group of „the rich“ derived from Stloukal's criteria (N=153 individuals) is nearly three times larger than the group derived from Hrubý's classification. The demographic structure, representation of males and females, is in this case similar to that of the whole Mikulčice-Kostelisko burial site, i.e. females clearly predominate (e.g. Velemínský et al. 2005). It is thus natural that the group of individuals with a rich grave inventory differs from the other individuals at Kostelisko in a smaller number of traits.

Table 5 lists the results of the verification of the different incidence of non-metric traits in both groups with the aid of the measure of divergence. This test criterion did not show any difference in the incidence of any trait, nor of any group of traits. The total mean measure of divergence lies on the 5% level of significance – 111.4.

The following is a summary of the aforementioned attempts to find "ancestral" traits within the group of individuals with rich grave equipment:

1. More favourable results were yielded when comparing group I of rich graves selected according to Hrubý's criteria, which demonstrated statistically significant differences in the incidence of more traits. On the other hand, the demographic structure of this group was clearly different from the situation in the rest of the burial site, and sexual dimorphism probably played a significant role in the incidence of several traits. Nonetheless, a number of traits within the group of individuals with a rich grave inventory may still represent ancestral heredity.
   - both statistical criteria showed a difference in the incidence of: *foramen infraorbitale partitum, foramen Vesalii a ponticulus atlantis posterior*, or *fossa Alleni*
   - statistically significant values using only the χ^2- test were further demonstrated in the case of: *tuberculum zygomaxillare, facies articularis trochlearis partita* and *torus mandibularis*
2. Group II of individuals with rich grave equipment derived using the classification of Stloukal (1970) was too extensive in relation to the population group buried at Kostelisko. Its demographic structure more or less corresponded to the situation in the whole burial site. The statistically significant differences demonstrated by the smaller group I, which is practically part of this group, were not demonstrated in this case.
   - using the χ^2- test, a statistically significant difference in incidence was shown in the case of the following traits: *sutura incisiva, processus temporalis ossis frontalis, foramen condylaris, facies Charlesi, facies articularis talaris anterior et media, crista solei* and *fossa sole.*
   - another test criterion, the measure of divergence, did not confirm any one of the aforementioned differences.

3.2 Morphological similarity of individuals at the Mikulčice-Kostelisko burial site

In the last phase of this work, we attempted to find groups of individuals in whom biological relatedness could be expected, based on the incidence of selected non-metric traits. We focused mainly on individuals buried with rich grave equipment. We proceeded basically using two approaches. The first was based on the premise that the graves of family members could neighbor on each other, or were located

Table 5. Comparison of the graves with rich equipment II (Stloukal 1970) with the other individuals buried at Kostelisko using the measure of divergence. Explanatory notes: statistically significant values at p=0.05 are in bold italics; statistically significant values at p=0.05 and p=0.01 according to Sjøvold's criteria (1973) are in italics

traits	Mikulčice-Kostelisko - the Graves with Rich Goods			Mikulčice-Kostelisko - the Graves with Poor Goods			Measure of Ddivergence					
	N	Incidence	%	N	Incidence	%	MD	p=0,05	p=0,01	S^2 MD	Left Endpoint of 95% Confidence Interval	Right Endpoint of 95% Confidence Interval
sutura incisiva	137	35	25,5	309	128	41,4	*0,10413*	0,03161	0,06321	0,01543	-0,13935	0,34762
proc. temp. os. front.	70	3	4,3	171	-	-	*0,15380*	0,06040	0,12080	0,02266	-0,14127	0,44887
os. sut. lambdoid.absens	70	17	24,3	234	88	37,6	*0,06537*	0,05568	0,11136	0,02625	-0,25220	0,38294
fac. Charles+f.ac. cond. media	33	24	72,7	239	89	37,2	*0,49834*	0,10346	0,20692	0,10200	-0,12764	1,12431
fac.art. tal. ant. et med. (Ta)	62	15	24,2	209	29	13,9	0,04935	0,06274	0,12548	0,00409	-0,07600	0,17470
fac. art. tal. ant. et med. com absens(Ta)	63	15	23,8	209	30	14,4	0,03807	0,06197	0,12395	0,00480	-0,09769	0,17383
for. supratrochleare	46	11	23,9	180	24	13,3	0,04796	0,08188	0,16377	0,00561	-0,09878	0,19470
sulcus frontalis	77	34	44,2	232	74	31,9	0,04688	0,05189	0,10378	0,00124	-0,02214	0,11590
os zygomaticum absens	112	3	2,7	280	21	7,5	*0,03858*	0,03750	0,07500	0,05419	-0,41768	0,49483
can. condylaris absens	31	5	16,1	57	19	33,3	0,11375	0,14941	0,29881	0,13638	-0,61007	0,83757
for. hypogl. bipart.	97	7	7,2	262	48	18,3	*0,10192*	0,04238	0,08476	0,05323	-0,35029	0,55414
for. suprascap.	42	4	9,5	165	4	2,4	0,06922	0,08961	0,17922	0,02539	-0,24307	0,38151
fossa pharyng.	185	44	23,8	53	24	45,3	*0,18498*	0,07282	0,14564	0,05064	-0,25608	0,62604
fossa costaclavic.	60	15	25,0	187	33	17,6	0,01043	0,06604	0,13209	0,00616	-0,14345	0,16431
fossa pector.maj.	62	0	-	243	17	7,0	*0,26637*	0,06073	0,12147	0,18042	-0,56616	1,09891
fossa teres	67	0	-	284	12	4,2	*0,15300*	0,05534	0,11068	0,14603	-0,59598	0,90199
fossa hypotroch.	86	3	3,5	274	26	9,5	*0,04748*	0,04583	0,09167	0,06432	-0,44959	0,54455
crista hypotroch.	49	22	44,9	198	63	31,8	0,04741	0,07638	0,15275	0,00273	-0,05497	0,14980
fossa solei	70	6	8,6	183	37	20,2	*0,09483*	0,05925	0,11850	0,06909	-0,42035	0,61002
crista solei	40	16	40,0	149	35	23,5	*0,09608*	0,09513	0,19027	0,00356	-0,02082	0,21298

Table 6. Comparison of skeletons from the graves with rich equipment II (Stloukal 1970) with the other individuals at Kostelisko on the basis of the group of non-metric traits using the mean measure of divergence. Explanatory notes: statistically significant values are in bold italics

Trait Group	MMD	S^2mmd	MDD-1,96 S^2mmd	MDD+1,96 S^2mmd
cranial sutures	0,10777	0,00715	-0,05796	0,2735
articular facets	0,15843	0,00728	-0,00882	0,32567
vessel and nervous foramina	0,7407	0,01082	-0,12978	0,27792
areas of muscle/fibrous insertions	0,11257	0,00817	-0,0646	0,28975
Total	***0,1114***	0,00244	0,01467	0,20813

in the same section of the burial site. This means that we based ourselves on the topography of the Kostelisko burial site. In the second phase, we used cluster analysis to determine the degree of morphological similarity of the skeletons from Kostelisko.

3.2.1. Morphological similarity of individuals in relation to the topography of the burial site and grave equipment

The topography of the burial site may also to some extent reflect structure, social hierarchy, previous societies or it may testify to the biological ties of the buried individuals. Naturally, one cannot expect that the position of the grave of each individual was strictly given and that we could be capable according to this position of determining the specific social position of the buried individual. The chronological succession of the death of individuals naturally always played an important role. The burial site was extended in a certain direction or certain directions.

On the other hand, ethnological studies indicate that the position of graves within the burial site was also determined by other facts. Socially important persons were usually buried at "special locations" within the burial site. We often find their graves in the centre of the burial site – the further a grave was located from the centre, the lower the expected social rank of the deceased. Once Christianity prevailed, such persons were often buried within church objects. The age of the deceased could also play an important role; children were more often buried at the edge of burial sites. The location of the grave could have also been selected with regards to the family or clan relationships of the deceased. The orientation of the graves could have also been affected for example by the season, position of the sun, i.e. previous faith, religion (e.g. Aries 2000).

The validity of some of these presumptions is not unrealistic even in the case of the Mikulčice burial sites. Which is why, out of interest, we focused on the relationships between the incidence of non-metric traits, the character of grave equipment and the grave position within the burial site. If we look at the map of the Kostelisko burial site with the graves with rich equipment according to Hrubý and Stloukal marked, we find the following:

- if a narrower selection according to Hrubý's criteria is used, then it is apparent that rich graves are concentrated in a wider cluster in the western and central section of the burial site. This is definitely not the case of a concentration into a single smaller place, as if we connect the "marginal" rich graves we get a more or less wider "oval" cluster of graves. Graves No 1778, 1890 are situated apart in the southern section, as are graves no. 1975 and 1980 in the western sector. At the edges of the burial site, we find exclusively graves with poor equipment or graves lacking equipment. This situation may be interpreted in several ways:
  - socially important individuals were buried in the centre of the burial site; family ties could also play a role.

- this state is contingent to the embracing of Christianity; older, pagan graves are in the centre, younger burials around these are in the spirit of Christian customs.
- this is a random state, burials were conducted only according to the chronological succession of death
- using the wider selection (Stloukal 1970), graves with rich equipment are found more or less throughout the burial site (Z-V), although they are yet again localised mainly in the western and central section of the burial site. The cluster of rich graves is not as apparent, significantly more graves "deviate". Nonetheless, "centralisation" of the rich graves, enclosed by graves without equipment is apparent.

We must also take into consideration that the burial site at Kostelisko has not been completely explored, its boundaries have not been determined. Certain graves with rich equipment thus need not have been detected by archaeological research.

In view of the aforementioned, we placed the incidence of non-metric traits i.e. the morphological similarities of individuals in the context of the topography of the burial site at Kostelisko. We focused only on individuals from graves with rich equipment according to Hrubý´s criteria (1955). The reason for this was the fact that this group differed in the incidence of several traits. Some of these may, despite the atypical demographic composition of the group, represent ancestral heredity. We proceeded as follows:

- we selected individuals in whom non-metric traits that could be, with some exaggeration, taken to be "ancestral" occurred and we compared the mutual position of their graves
- similarly, we also compared the incidence of other non-metric traits in individuals with rich equipment according to Hrubý, i.e. the mutual position of the graves of individuals with a concordant incidence of non-metric traits.
- we selected individuals with a concordant incidence of several non-metric traits, regardless of the mutual position of their graves.

The following list includes for each non-metric trait the number of the graves/skeletons, in which the relevant trait occurred as well as information whether there existed a "topographic" relationship between the cited graves. First, we list the morphological traits in whose incidence the group of "rich" individuals differed statistically (medium bold-type, italics), followed by traits with a low population incidence occurring in individuals from more distant graves.

- ***foramen infraorbitale partitum***
  grave 1705, 1711, 1752, 1778; in the vicinity of 1711 and 1752
- ***foramen Vesalii***
  graves 1750, 1766, 1908, 1952; in the vicinity of *1908* and *1952*, 1750 and 1766 in the same sector
- ***ponticulus atlantis posterior***
  graves 1809, 1902, 1903; in the vicinity of 1902 and 1903
- ***facies articularis trochlearis partita***
  graves 1616, 1705, 1908, 1980; different position of graves
- ***torus mandibularis***
  graves 1665, 1778; different position of graves
- **facies articularis talaris anterior absens**
  graves 1662, 1766; lie in the vicinity
- **foramen supraorbitale**
  graves 1752, 1840, 1975; in the relative vicinity of *1752* and *1840*
- **torus acusticus**
  graves 1677, 1711, 1748, 1778, 1879, 1952; in the vicinity of *1711* and *1748*
- **ponticuli sellae**
  graves 1616, 1665, 1879; next to each other *1616* and *1665* /
- **tuberculum praecondylare**
  graves 1665, 1908, 1912; in the vicinity of *1908* and *1912* !
- **spina trochlearis**
  graves 1702, 1750, 1759, 1879, 1952; graves in the same sector (1702, 1750, 1759)
- canalis condylaris
  graves 1742, 1752, 1766, 1778, 1809, 1908; in the vicinity of *1742* and *1752*, *1778* and *1809*,
- fossa bicipitis
  graves 1705, 1746, 1903; in the relative vicinity of 1705 and 1746
- torus maxillaris
  graves 1662, 1665; graves in the same sector
- trochanter tertius
  graves 1952, 1980; graves in the same sector

- fossa solei
  graves 1752, 1912; different position of graves
- crista solei
  graves 1908, 1980; different position of graves
- incisura faciei lunatae
  graves 1702, 1742, 1759, 1879; different position of graves
- facies articularis sacralis accessoriae
  graves 1809, 1903; different position of graves
- facies Charlesi (this is not a population rare trait)
  graves 1711, 1742, 1778, 1809, 1908, 1912, 1975, 1980; graves located in the vicinity of 1778 and 1809; 1908 and 1912
- facies articularis condylaris media (this is not a population rare trait)
  graves 1705, 1742; located in one sector
- facies articularis tibialis accessoriae lateralis (this is not a population rare trait)
  graves 1742, 1766, 1908, 1912, 1952, 1980; group 1908, 1912 and 1952
- facies articularis talaris anterior et media (this is not a population rare trait)
  graves 1655, 1677, 1689, 1711, 1746, 1778, 1809, 1908, 1912, 1952; certain graves in the vicinity e.g. group 1908, 1912, 1952
- facies articularis talaris anterior et media communis (this is not a population rare trait)
  graves 1616, 1742, 1746, 1752, 1759, 1975, 1980; in the vicinity of group 1742, 1752, 1759 ?
- sulcus frontalis (this is not a population rare trait)
  graves 1662, 1675, 1730, 1750, 1809, 1879, 1975
- foramen frontale
  1677, 1702, 1711, 1730, 1752, 1759, 1809, 1840, 1980; different position of graves, in the vicinity only 1752 and 1840
- foramen parietale absens (this is not a population rare trait)
  graves 1616, 1752, 1759, 1766, 1778, 1902, 1908, 1952, 1980; in the vicinity of 1908 and 1912

Thus, there are not many cases where a population rarer non-metric trait occurred in the vicinity of the buried individuals.

- individuals from graves 1711 and 1752 concur in the incidence of *foramen infraorbitale partitum*
- individuals from graves 1908 and 1952 concur in the incidence of *foramen Vesalii* (1750 and 1766)
- individuals from graves *1902* and *1903* concur in the incidence of *ponticulus atlantis posterior*
- individuals from graves 1662 and 1766 concur in the incidence of *facies articularis talaris anterior absens*
- individuals from graves 1752 and 1840 concur in the incidence of *foramen supraorbitale*
- individuals from graves 1711 and 1748 concur in the incidence of *torus acusticus*
- individuals from graves *1616* and *1665* concur in the incidence of *ponticuli sellae*
- individuals from graves *1908* and *1912* concur in the incidence of *tuberculum praecondylare*
- individuals from graves 1742 and 1752 , 1778 and 1809 concur in the incidence of *canalis condylaris*
- individuals from graves 1705 and 1746 concur in the incidence of *fossa bicipitis*

3.2.2 Groups of morphologically similar individuals derived by cluster analysis

There are not many statistical methods that may help separate individuals with the same incidence of non-metric traits. Of the classical statistical procedures, previous research used the modification of Bayes´ calculation of a posterior probability (Alt/Vach 1992; Alt/Vach 1998), cluster analysis (Wiltschke-Schrotta 1988; Coppa et al. 1998), logistic regression (Iregren/Isberg1991) and the modification of the "correlation" coefficient (Heinrich/Teschler-Nicola 1991). We did not take into consideration directly for these goals the procedure proposed by Sjøvold (1976-77) and Ullrich's method (e.g. 1969). We would apply Sjøvold's procedure if we could compare individuals on the basis of the same non-metric traits. This though was not possible due to the state of preservation of the skeletons. The interpretation of the results of analogical works is not unequivocal as a rule, the conclusions are easily disputed hypotheses. The error naturally need not involve the applied statistical method, but also the selection of traits. It also cannot be ruled out that the eventual concurrence represents a random phenomenon. Very often, the average incidences of the compared traits in the studied population are also not verified. Thus, from the aspect of this issue, series of skeletons with corroborated genealogical data are extremely valuable (e.g. Bouquet-Appel 1984; Sjøvold 1986; Carson 2006).

For the reasons cited in the methodology, we compared only groups of certain individuals according to the incidence of certain traits. We did not compare all the individuals on the basis of all monitored traits. When selecting the traits, we proceeded according to their character and function or according to their localisation. In the first phase, we focused only on the group of individuals with rich grave equipment (Hrubý 1955), and in the next phase on the whole population buried at Kostelisko. We mention the results only of some comparisons.

3.2.2.1 Group of individuals with rich grave equipment (Hrubý 1955)

- comparison according to hyperostotic non-metric traits (*torus palatinus, torus maxillaris, torus mandibularis, trochanter tertius*/N=12)
  similarity is demonstrated by graves No:
  - 1677, 1952
  - 1746, 1752, 1759

3.2.2.2 The Mikulčice-Kostelisko population group

- comparison according to non-metric traits related to sites of muscle attachment (loss of bone tissue) (*fossa pectoralis major, fossa teres, fossa costoclavicularis, fossa hypotrochanterica, fossa solei*/N=24)
  similarity is demonstrated by graves no.:
  - 1679, 1784, 1908, 1980
  - 1680, 1912, 1939, 1963b, 2001
  - 1892, 1945
  - 1918, 1954, 1989,
- comparison according to hyperostotic traits (*torus palatinus, torus occipitalis, torus maxillaris, torus mandibularis, trochanter tertius*/N=49)
  similarity is demonstrated by graves no.:
  - 1861 and 1938;
  - 1837 and 1918;
  - 1576, 1578, 1598, 1765, 1778,1909
  - 1596, 1728, 1831, 1907, 1913, 2003, 2005
- comparison according to non-metric traits of the pterion region (*os epiptericum, sutura frontotemporalis, processus frontalis ossis temporalis, processus temporalis ossis frontalis, processus parietalis ossis sphenoidalis*/N=59)
  similarity is demonstrated by graves No:
  - 1765, 1835, 1999;
  - 1777a, 1967;
- comparison according to non-metric traits relating to interposed ossicles in the cranial sutures (*ossiculum bregmaticum, ossiculum suturae sagittalis, ossiculum lambdae, ossiculum suturae lambdoidae, ossiculum asterii*/N=28)
  similarity is demonstrated by graves No:
  - 1578, 1637, 1708
  - 1963b, 1985, 1989

Most comparisons turned out to lack any great predicative value – the number of individuals (and traits) compared was usually low. This applied especially to the group of individuals with rich grave inventory. A slightly more ideal situation was when we included all the individuals at the burial site. The dendograms thus acquired do not allow for any general conclusions. The morphological similarity of certain graves suggested by one group of non-metric traits was not confirmed by another group of traits. Individuals who feature in one comparison often could not be compared according to the incidence of other traits. The poor preservation of skeletons turned out to be a greater limiting factor than initially presumed. The selection of another procedure, or resolution of the problem of missing bones, is thus necessary. The results of the comparison using cluster analysis nearly did not concur with the conclusions of the evaluation of relationships between morphological concurrence and burial site topography.

4. Summary and conclusion

Thanks to the aforementioned procedure, we were able to find within a group of rich graves traits that had a different incidence in view of the average population incidence at Kostelisko and then of setting apart individuals with greater morphological concurrence, i.e. with a greater probability of being biologically related. A more favourable result was obtained when comparing smaller groups of individuals from graves with rich equipment as defined by Hrubý's criteria (Hrubý 1955), and which showed statistically significant differences in the incidence of several traits that may represent ancestral hereditary non-metric traits (*foramen infraorbitale partitum, foramen Vesalii* a *ponticulus atlantis posterior*, eventually *fossa Alleni*). If we presume that more than one family is buried at Kostelisko, it is more realistic to contemplate that the cumulation of common, population rare traits here need not be so great as in the case of a small ancestral burial site. This means that in the case of an "ancestral" trait, we may also expect a low average population incidence due to the amount of individuals (families) at the burial site. Thus, we need not detect such traits when comparing average population frequencies of these traits. From this aspect, the situation at a large burial site is not as "optimal" as in the case of a smaller "ancestral" burial site, where the morphological similarity should be theoretically greater. Although we showed in the group of individuals from graves with rich equipment (Hrubý 1955) statistically significant differences in the incidence of several traits, none of these may be unequivocally considered to be ancestral. The reason for this is also the small number of evaluated individuals for each trait within this group of "rich" individuals.

According to the incidence of selected non-metric traits (possible "ancestral" traits), we then attempted to find groups of individuals who would be expected to be biologically related. Our premise was that the graves of biologically related persons could neighbor on each other, or could be located in the same sector of the burial site. For the same purposes, we also used cluster analysis. The results of both comparisons almost did not concur.

One must take into consideration that with the aid of non-metric morphological traits we may only determine that the probability of biological relatedness between certain individuals is greater or smaller than between other individuals. A more ideal situation is in the case of smaller groups, where kinship is also indicated by the archaeological findings situation. This is why it is suitable also to use other methods for the verification of biological relatedness in the case of anonymous skeletal material. Mainly, attempts should be made to isolate bone deoxyribonucleic acid and subsequently compare specific nucleotide sequences (TRNP).

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P. Velemínský/L. Poláček (Hrsg.), Studien zum Burgwall von Mikulčice VIII. Brno 2008, 321-343
Anthropological and epidemiological characterization of Great-Moravian population in connection with the social and economic structure

Dental Morphological Traits in a Population from a Settlement of the Mikulčice Agglomeration

Kristina Krchová[1] – Petr Velemínský[2]

This study is devoted to research the dental morphological traits in old Slavonic population in Mikulčice agglomeration (9th-10th century A.D.). The sample consists from two burial sites – Mikulčice-Kostelisko and Mikulčice-Klášteřisko. Dental traits could be evaluated in 401 adult individuals from both burial sites. Of these, 110 were men, 147 women and the rest were individuals of undetermined sex. The twenty-two morphological traits were studied for teeth of the upper jaw and the seventeen traits for teeth of the lower jaw according to ASU DAS methodology. As sexual dimorphic were statistically proven the hypocone on the upper third molars and one-rooted of the first upper premolars – this traits were more frequent in females. While in males were more frequent the two-rooted the first upper premolars. The inter-population comparison between Great Moravian sample from Mikulčice and Scandinavian samples indicate the highest concordance in occurrence of the dental morphological traits.

Key words: Great Moravian population – dental traits – sexual dimorphism – inter-population comparison

1. Introduction

Dental morphological traits (non-metric or dental variety) may be divided into three groups: traits that occur on the crown itself, traits associated with the morphology of teeth roots, and traits associated with the size and number of teeth or their position within the dental arch. On the crowns of teeth, we monitor the number and size of cusps (e.g. tuberculum Carrabelli, the fifth cusp on the lower molars), the position of grooves (interruption groove on the upper incisors), the shape of grooves (the pattern of grooves on the lower molars) and the course of grooves (deflecting wrinkle), the incidence of accessory ridges (mesial accessory ridge). We also monitor the number of roots of premolars and molars. Finally, it is possible to evaluate the position of teeth within the dental arch and deviations in the number of teeth (hypodontia, hyperdontia).

Dental morphological traits have been known since the mid 19th century, when a cusp located on the lingual edge of the medial cusp of the first upper molar was described and termed tuberculus *anomalus*, later named *tuberculum Carabelli* after its discoverer (Hillson 1996). Until the 1920s, only the presence/absence of morphological non-metric traits was evaluated. A number of traits, in reality, are of morphognostic character, i.e. continuous developmental intermediate stages exist between the absence and "clear" presence of these traits. The first person to reflect this fact in his research was Aleš Hrdlička who proposed an evaluation classification of the shovelling of upper incisors of the native inhabitants of North America (e.g. Turner/Nichol/Scott 1991, Hillson 1996). The American anthropologist

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Fig. 1. Plaster model of ASU DAS (Turner/Nichol/Scott 1991).

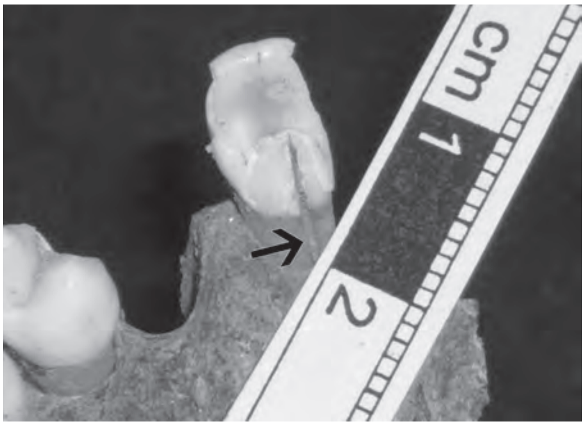

Fig. 2. Interruption groove U1P (Mikulčice grave No 1256).

Dahlberg then contributed significantly to the elaboration of a methodology for evaluating dental variations. He proposed a multi-stage classification – plaster models of individual stages – of dental variations for other traits (Turner/Nichol/Scott 1991). Later on, the Americans Scott and Turner from Arizona State University based themselves on his work and created the co-called "Arizona State University Dental Anthropology System"(ASU DAS) (Turner/Nichol/Scott 1991). This is a method of evaluation of 23 traits described on the teeth of the upper jaw and 21 traits described on the teeth of the lower jaw. Apart from proposing a classification for evaluating new traits, they unified the methodology for evaluating variations already studied previously. The plaster models of the developmental stages of individual teeth variations may be considered to be the greatest advantage of ASU DAS (Fig. 1). These, along with the description itself help unify the evaluation of various researchers and decrease the probability of inter-observer error. Currently, most studies consecrated to dental traits apply the ASU DAS. This relates not only to both American continents (Griffin 1989; Haydenblit 1996; Scherer 2004; 2005; Bartolomucci 2006), but also to Asia (Tsai et al. 1996; Hsu et al. 1999; Matsumura 2005; Matsumura/Hudson 2007), Africa (Irish 1997; Edgar 2002, 2007) and partially Europe (Manzi/Santandrea/Passarello 1997; Coppa et al. 1998). In Europe, apart from the ASU DAS, we may encounter the method of evaluation of dental traits proposed by K. Alt (e.g. Alt 1991; Alt/Vach 1998; Desideri 2007) while in Eurasia we may come across the methodology of A.A. Zubov (Kaczmarek 1992; Tóth 1992).

At the beginning, it was presumed that monogenic type of heredity could apply to teeth variations. In the inter-war period, though, it was shown that a number of traits demonstrate a polygenic type of heredity, with a various range of developmental traits. The issue of dental trait heredity has been the subject of studies involving mono- and dizygomatic twins and "family" research (e.g. Berry 1978; Wood/Green 1969; Goose/Lee 1971; Biggerstaff 1973; Townsend et al. 1992; Staley/Vance/Louck 1998). Dental morphological traits started being used for inter-population comparisons in the 1960s, in parallel with discrete (epigenetic) morphological traits described on the skeleton. Apart from resolving relationships/similarities associated with the effort to clarify previous population migration, and the course of ethnogenesis in various geographical regions (e.g. Turner 1967; Irish 1997, 2006; Hsu et al. 1999; Matsumura 2005, 2006; Khamis et al. 2006), dental traits are also used in the area of human evolution studies. An example of this may be the resolution of the issue of the relationship between modern man and his evolucionary predecessors (e.g. Irish 1998;

Bailey 2000, 2006; Skinner et al. 2008). For example, S.E. Bailey (2006) focused in her work on the variability of dental traits in Neanderthal forms, whilst proving more or less the continuity of the incidence of these traits in the evolutionary line Homo erectus – early form of Homo neanderthalensis – early forms of Modern Man from the Near East and finally Upper Palaeolithic anatomically Modern Man. Similarly, J.D. Irish (1998) in his work states that a number of traits typical of the Sub-Saharan population also appear in early hominids, as well as in primates.

A prerequisite for comparing various population groups on the basis of dental or osteological traits is the verification whether their incidence is not statistically significantly sex-dependent. In the case of bilateral traits, it is then suitable to verify whether an asymmetrical incidence is or is not preferred. Naturally, the basic condition is to determine the frequency of individual traits within population groups.

To date, a statistically significant sexual dimorphism valid simultaneously for several population groups has not been proven for any dental trait (Manzi/Santandrea/Passarello 1997; Ullinger et al. 2005). The association of traits with sex must thus be tested in every population studied.

Inter-population comparisons have shown statistically significant differences in the incidence of dental traits between the inhabitants of certain continents. An example of this is the tuberculum Carrabelli typical of the European population, or the marked medial ridge on the upper incisors and the diastema mediale typical of the African population, especially Bushmen, and the shovelling of upper incisors that has a high incidence among Asian populations (Yaacob/Narnbiar/Naidu 1996). Based on these results, the so-called "Mongoloid, Caucasoid and African dental complex" has been introduced. The Mongoloid dental complex includes shovelling of the upper incisors, cusp 6 and 7 on the lower molars, deflecting wrinkle and protostylid on the first lower molar. On the contrary, the Caucasoid dental complex is characterised by the following

Fig. 3. Hypocone absent U3M (Mikulčice grave No 1174).

Fig. 4. Hypocone UM3 (Mikulčice grave No 1174).

traits: absence of the shovelling trait on the incisors, absence of additional cusps on premolars, low frequency of the cusp 6 and 7 traits, frequent incidence of the tuberculum Carrabelli, protostylid and winging (Hillson 1996).

During the study of dental morphological traits in previous populations, researchers encounter several problems. Naturally, the biggest problem is the incomplete preservation of dentition and especially dental abrasion in adult individuals. A number of teeth cannot be evaluated also because of the presence of caries. This means that from an apparently large burial site with several hundred burials, in the end only tens of individuals can be evaluated. Our research is after all a good example of this. Problems then arise if we wish to compare the group studied with

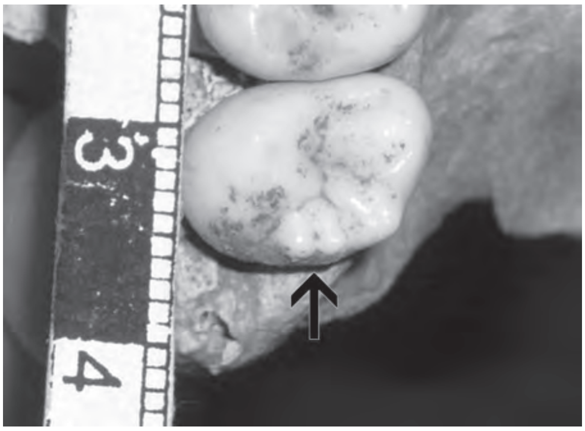

Fig. 5. Metaconule UM3 (Mikulčice grave No 1323).

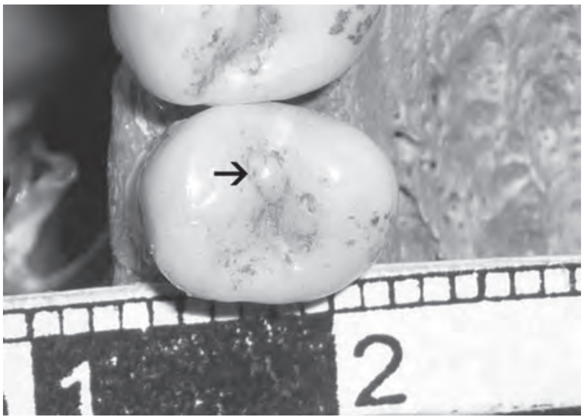

Fig. 6. Odontome U2P (Mikulčice grave No 1323).

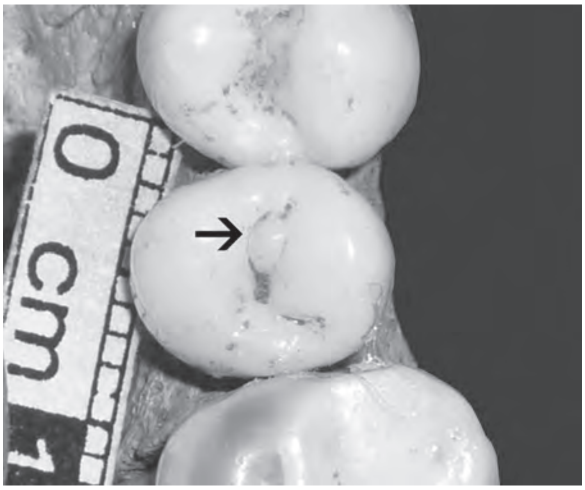

Fig. 7. Odontome UP2 (Mikulčice grave No 1323).

other populations. For comparison it is suitable to choose populations where the dental traits were evaluated using the same method. In view of the fact that most Central and East European groups were previously evaluated on the basis of A. A. Zubov's method (Tóth 1992; Kaczmarek 1992), there is a lack of comparative data. Finally, not even a unified methodology can guarantee problem-free inter-population comparison. It has been shown that not even authors who use the ASU DAS determine the presence of traits with multi-stage evaluation on the basis of the same developmental stages (e.g. Edgar 2002; Scherer 2004; Bartolomucci 2006). This results in variations in the frequency of the same trait due to the more lenient or stricter limit for acknowledging its presence. If studies publish "limit" stages, then there is no problem, as the frequency may be calculated. Furthermore, even in the case of the ASU DAS, the subjective view of the given researcher plays a role – allocation to a concrete developmental stage may be controversial. 3D imaging methods and the subsequent application of sophisticated computer and statistical software may contribute towards a more exact and objective evaluation of dental traits (e.g. Mayhall/Kageyama 1997).

The aim of our contribution is to determine the frequency of selected dental morphological variations in the Great Moravian Population from a settlement of the Mikulčice agglomeration and to compare this population group with other, analogically dated populations of Central Europe.

2. Material and method

We studied the dental morphological traits in individuals from two burial sites from a sub-castle of the Mikulčice power centre. These included the burial site at Klášteřisko, where 301 graves were uncovered (Stloukal/Hanáková 1985) and the burial site located in the Kostelisko position, the second largest Mikulčice burial site with 425 graves (Velemínský et al. 2005). Both burial sites had not been explored completely (Poláček/Marek 2005).

Dental traits could be evaluated in 401 adult individuals from both burial sites. Of these, 110 were males, 147 females and the rest were individuals of undetermined sex. All individuals with an evaluable dentition were processed from the Klášteřisko burial site (N=185), while only individuals with excellent or very good preservation of dentition were evaluated from the Kostelisko burial site (N=216). We extended the group to include the individuals for Kostelisko because of the insufficient number of individuals with evaluable dentition buried at the Klášteřisko site.

During the evaluation of dental traits, we based ourselves on the methodology proposed by Ch. G. Turner (Turner/Nichol/Scott 1991; Scott/Turner 1997). As stated above, this is the so-called Arizona State University Dental Anthropology System (ASU DAS), which apart form verbal definitions of traits and developmental stages also includes their plaster models. We evaluated 22 morphological traits for teeth of the upper jaw and 17 traits for teeth of the lower jaw (see Table 1). Apart from variations with evaluation of presence/absence, we also studied traits of a morpho-gnostic character, i.e. where the presence of a given trait is presented by various, continuous developmental stages. Finally, this study also included traits for which every "category" is evaluated as an independent trait. This group included the following traits: winging of the upper incisors (1A, 1B-bilateral rotation, 2-unilateral rotation, 3-direct, 4-inverse winging), interruption groove of upper incisors (0-absent, 1-mesial groove, 2-distal groove, 3-concomitant mesial and distal groove, 4-medial groove), the number of cusps on the lower molars (4, 5, 6), groove pattern of lower molars (Y, X, +, others) and the number of roots of premolars and molars.If premolars or molars are missing, the number of roots can be determined according to the preserved teeth alveoli.

Before statistical processing, it was necessary to calculate the incidence of bilateral traits per "individual", as recommended by the authors of the ASU DAS (Turner/Nichol/Scott 1991). When expressing the incidence per individual, the trait is taken to be present on the one hand if it is present on both the right and left tooth (1-1), and on the other if it is present only on one side (1-0, 1-*). The trait that is missing both on the right and on the left side (0-0) is naturally taken

Fig. 8. Triple-rooted U2P (Mikulčice grave No 969).

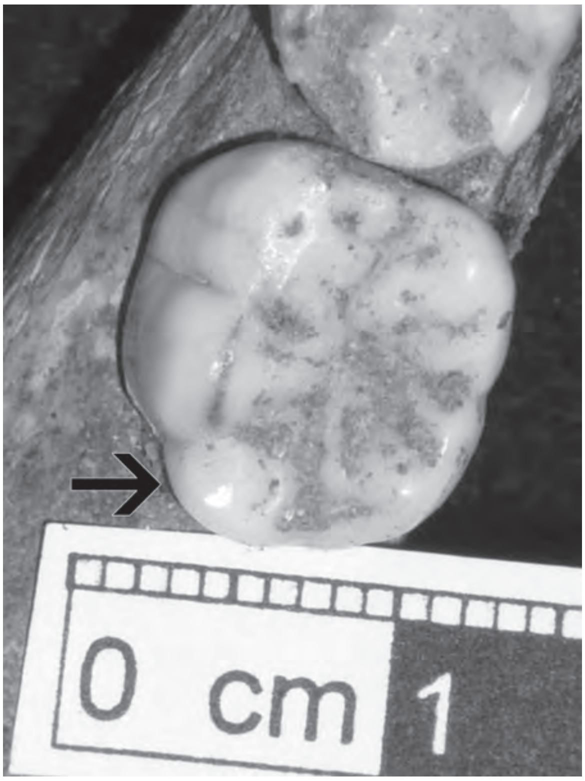

Fig. 9. Cusp 5 LM1 (Mikulčice grave No 1253).

to be absent.A different situation arises if the trait is absent on one side and cannot be evaluated on the other (0-*). In this case, if we express the incidence per individual, we consider this trait to be non-evaluable (*), as the absence/presence of this trait on the missing side cannot be ruled out.This procedure is respected by most current studies (e.g. Haydenblit 1996; Manzi/Santandrea/Passarello 1997; Irish 2006; Edgar 2007; Krchová/Velemínský/Peterka 2007).

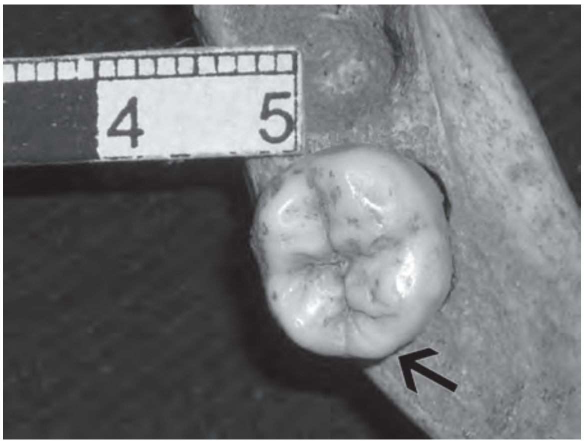

Fig. 10. Cusp 5 L3M (Mikulčice grave No 1327)..

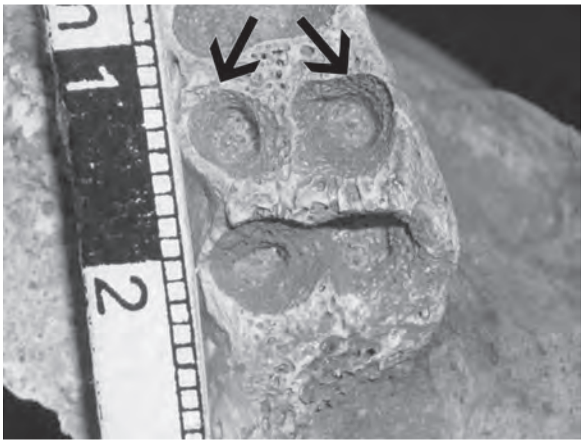

Fig. 11. Double-rooted UP1 and UP2 (Mikulčice grave No 1348).

Fig. 12. Shovelling UI1, UI2, UC (Mikulčice grave No 1286).

The original aim to compare the Great Moravian population from Mikulčice with a similarly dated and geographically close European population group in which the ASU DAS was applied could not be undertaken because of the absence of such a study. From Central Europe, the only population group available was the recent Czech population of children and adolescents aged between 7 and 21 years (Krchová/Velemínský/Peterka 2007). We further chose a Middle Ages population from Scandinavia. This included three groups: from the period when Greenland was settled (OG, dated in 10^{Th} century) and from the medieval Greenlandic (SvG) and Norway (Nor) groups (Scott/Alexandersen 1992). Finally, the last population used in the comparison dates to the Roman Imperial period, more precisely the 2^{nd} century AD. This includes individuals buried in the agricultural village of Lucus Feroniae and the city of Portus Romae (Isola Sacra necropolis) (Manzi/Santandrea/Passarello 1997).

Statistical processing was conducted using the MS Excel 2003 and Statistica 6.0 programs. We tested the zero hypothesis – the frequency of the incidence of dental traits in both sexes does not differ statistically – using the χ^2 test of good concordance. Inter-population comparison was conducted again using the χ^2 test of good concordance (e.g. Zvárová 2004). The levels of statistical significance of both tests were set at p=0.05. If the frequency did not reach at least a value of five, calculation of the Yates correction at a 5% level of statistical significance was used (Zvárová 2004).

3. Results

The shovelling trait was most frequently observed on the lateral incisors in a total of 50% of evaluated individuals. On the contrary, the double shovelling trait occurred in 23.04% of first premolars. The incidence of the tuberculum dentale was relatively frequent on the central and lateral incisors (Fig. 16, 18), with 33.33% of cases. The medial interruption groove occurred most frequently on the central and lateral incisors (14.89%, 27,73%) (Fig. 2). If we leave aside the high frequency of the type three winging, which is considered to be the norm, then the other type with a higher frequency is the state whereby one or both central incisors are rotated distally (4.05%).

The distal accessory ridge was very frequently observed on canines, 62.07% of cases. A very rare trait on premolars is the tri-cusped premolar. The incidence of the metacone is again considered to be normal in these populations and this corresponds to the frequency observed, exceeding 90% on all molars. The incidence of the hypocone had a descending tendency from the first molars down to the third molars (53.75%) (Fig. 3, 4). This is similar to the metaconule, whose frequency is highest in the case of first molars 38.21% (Fig. 5). Tuberculum Carabelli occurred most frequently on the first molars (Fig. 15). There is nearly no incidence of parastyle on the molars. The incidence of the odontome trait (13.04%) on the second premolars is interesting (Fig. 6, 7). Double rooted upper second premolars (Fig. 17) have low frequencies in our sample (16,67%). Three-root premolars were also rarely observed (Fig. 8) as were single-root first molars. In the case of the teeth of the lower jaw, the following frequency of traits was observed. Shovelling on the central and lateral incisors did not exceed 7%. The Y groove pattern was typical on the first molar (81.01%), while the + groove pattern was typical on the second molar (72.64%) and a different shape than Y, X or + occurred on the third molars (65.57%). On the lower molars, the protostylid is an analogous trait to the parastyle, which is not as rare though, as it has been observed on the first molars in up to 37.57% of cases. Interesting is the high incidence of cusp five (Fig. 9, 10) on the first molars (93.71%) and on the third molars (47.83%) (Fig. 19, 21). The cusp six and cusp seven were rarely observed on all molars. The incidence of two or three root first premolars and of three root second premolars and molars was not been observed at all. A more detailed overview of the frequency of incidence of dental traits is presented in Tables 2-3.

Fig. 13. Tri-cusped premolar U2P (Mikulčice grave No 969).

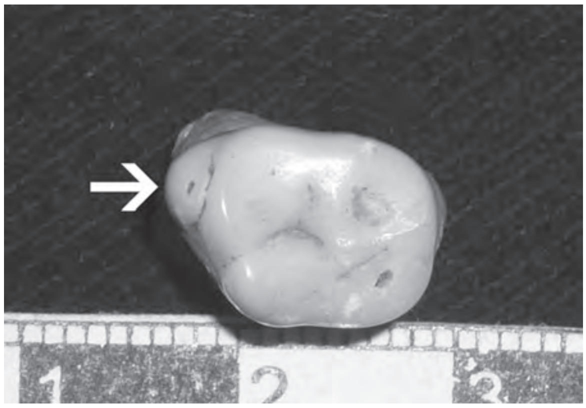

Fig. 14. Tuberculum Carabelli U2M (Mikulčice grave No 1030).

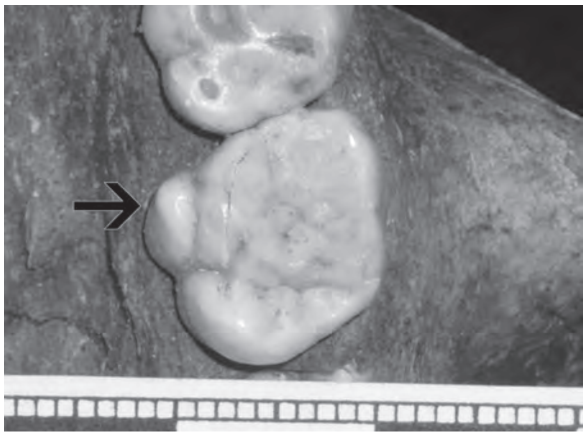

Fig. 15. Tuberculum Carabelli U1M (Mikulčice grave No 1253.)

Based on the observed frequencies, we tested the dependence of the incidence of dental nonmetric traits on sex (Tables 2-3). In our group, sex-dependent traits were found to include hypocone on the third upper molars, which was observed more frequently in females. Also more frequent in females were 1-root first upper premolars, while the 2-root premolars (Fig. 11) predominated in males. Traits involving the teeth of the lower jaw did not show any sexual dimorphism.

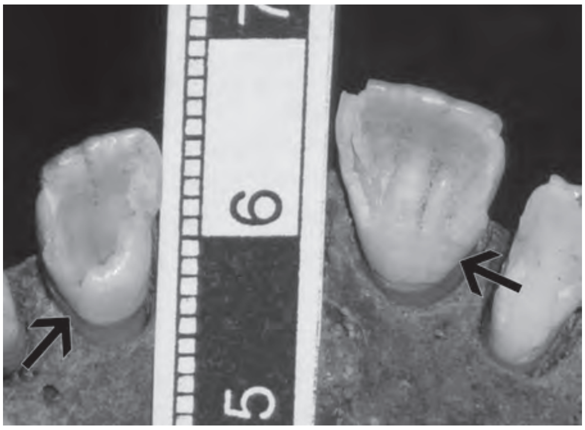

Fig. 16. Tuberculum dentale UI1 (Mikulčice grave No 1253).

Fig. 17. Double-rooted U2P (Mikulčice grave No 898).

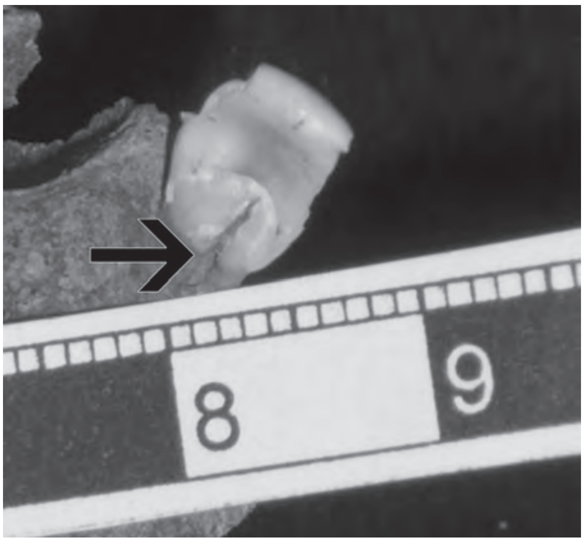

Fig. 18. Tuberculum dentale UI2 (Mikulčice grave No 1256).

We compared the population from Kostelisko and Klášteřisko with another five populations. We tried to select populations that would correspond either in date or geographically and in whose case the same method of evaluation of dental traits had been used. The first population used for comparison was a recent group from the then Czechoslovakia (Krchová/Velemínský/Peterka 2007). Both groups differed significantly in the incidence of the following traits: shovelling of the upper incisors and canines (Fig. 12), double shovelling and distal accessory ridge of the upper canines, metacone and cusp 5 on the first upper molars. According to the traits of the lower jaw teeth, these populations again differed most in the incidence of the distal accessory ridge on the lower canines, fovea anterior on the first molars, the incidence of a Y groove pattern on the second molar, the deflecting wrinkle and protostylid on the first molars. As to the other traits, the incidence of morphological traits on the teeth of both populations concurs (see Table 4). The Roman population and Mikulčice population again differed in the incidence of the following traits: shovelling of the upper incisors, tuberculum dentale on the upper canines, cusp 5 and parastylus on the first upper molars and the incidence of tuberculum Carrabelli on the upper three molars. As to the lower jaw, the situation was similar to the previous comparison with the recent population. Differences occurred in the case of the canine distal accessory ridge, fovea anterior, deflecting wrinkle on the first molars and the protostylid, which differed in the case of all molars (Table 5). The populations compared next originated from Scandinavia. The populations from the period of the settlement of Greenland (OG) and from Norway (NOR) differed most markedly, namely in the following cases: metacone on the first and second upper molars and cusp 7 on the lower second and third molars. A detailed list of the traits compared is found in Tables 6-7 On the contrary, the Greenland Middle Ages group (SvG) differed in only five traits, including cusp 5 on the second upper molars, 1-2 root second upper molars. In the case of the teeth of the lower jaw, the groups differed in the incidence of the cusp 7 on the second and third molars and in the cusp 5 on the third molars (Table 8).

4. Discussion and conclusion

The aim of this work was to determine the frequency of the incidence of selected dental morphological traits in a population from Mikulčice and to compare our results with other population groups. For this comparison, we did not have at our disposal studies with a similarly dated (early Middle Ages) and geographically close (Central Europe) population group evaluated on the basis of the ASU DAS.

In the Great Moravian population, we did not observe the incidence of the following traits: winging – bilateral rotation above 20° and unilateral rotation of one of the central upper incisors, distosagittal ridge on the second upper premolars, odontome on the first upper premolars, double shovelling of the central lower incisors, premolar lingual accessory cusp type 8 and 9 (Fig. 20) on the first lower premolars, medial trigonid crest on the lower first and second molars and distal trigonid crest on the lower second molars, „cusp 7“ on the lower second and third molars, 2- and 3-rooted lower first premolars and 3-rooted lower first molars. The following traits occurred with a lower frequency on the teeth of the upper jaw: double shovelling of the lateral incisors, 3-cusps on the first and second premolars (Fig. 13), tuberculum Carrabelli on the second and third molars (Fig. 14), parastylus on all molars, 3-rooted first premolars. The following traits occurred rarely on the teeth of the lower jaw: cusp 6 on the second molars and cusp 7 on the first molars. On the other hand, the following traits were represented most frequently: metacone all upper molars, 3-rooted the first and second upper molars, 2-rooted all lower molars.

As mentioned in the introduction, the association of the incidence of dental non-metric traits with sex may be considered population specific (e.g. Tsai et al. 1996; Irish 1997; Hsu et al. 1999; Scherer 2004; Ullinger et al. 2005; Khamis et al. 2006). In the Great Moravian population, sexual dimorphism was statistically proven in the case of the hypocone on the upper third

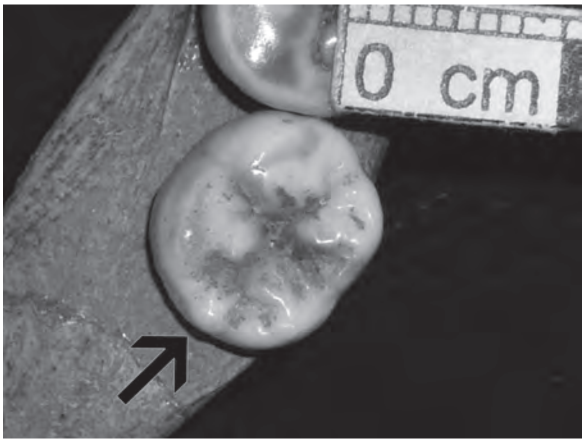

Fig. 19. Cusp 5 LM3 (Mikulčice grave No 1327).

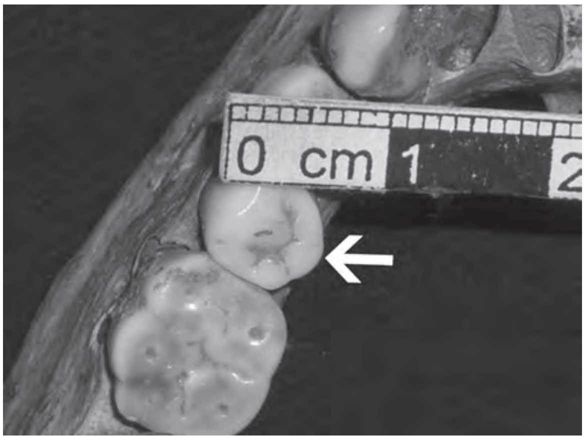

Fig. 20. Premolar lingual accessory cusps LP2 (Mikulčice grave No 1327).

Fig. 21. Cusp 5 L3M (Mikulčice grave No 1386).

molars – this trait was more frequent in females. In females, 1-rooted of the first upper premolars also predominated, while in males 2-rooted the first upper premolars were more frequent. On the contrary, in the Czech population from the 20th century, the incidence of the labial curve on upper incisors was sex-dependent, occurring more frequently in females (Krchová/Velemínský/Peterka 2007). For comparison, Edgar (2002) showed in the Modern Age population group from the Western European Von Luschan collection of the American Museum of Natural History a correlation with sex for the "peg shaped" upper incisors, the *fovea anterior*, deflecting wrinkle etc. For a number of traits tested, though, these studies did not involve sufficient frequencies of incidence, i.e. no general conclusions can be drawn from the results. This is where, unfortunately, the problem of unsatisfactory tooth preservation, namely preservation of occlusion surfaces, in adult individuals of determined sex comes into the fore.

We compared the Great Moravian population with another five populations. We tried to find studies involving similarly dated Central European skeletal groups on which the ASU DAS had also been applied. In view of the absence of such studies, we had to make a compromise and apply research from Scandinavia and Italy. An interesting point is the relatively high concordance of dental traits between the Great Moravian population from Mikulčice and the Middle Ages group from Greenland, where out of the 31 traits studied a similar incidence was noted in the case of 24 traits, i.e. a statistically significant difference in incidence was noted only in the case of 7 traits. A similar result was observed when comparing the Great Moravian population with the group dating from the settling of Greenland. In this case, both populations differed statistically in the incidence of 8 traits out of 31 studied. Based on the largest number of traits, we were able to compare the group from Mikulčice with the recent Czech population. Of the 57 traits studied, 14 traits had a statistically different incidence. The Roman population concurred with that of Mikulčice in 25 cases. The Roman population from the village of Lucus Feroniae and the city of Portus Romae (the Isola Sacra burial site), the Norwegian and the Czechoslovak population groups differed from the our group in the incidence of the cusp 5 on the first upper molars and in the prostostylid on the first molars. The Roman and Czechoslovak group differed from the one from Mikulčice in the shovelling traits on the upper first and second incisors, the tuberculum dentale on the upper canine, the canine distal accessory ridge on the lower canines, and the fovea anterior on the lower molar. All three Scandinavian groups- those from the period of the settlement of Greenland in the 10th century AD, the Middle Ages population of Greenland and Norway -also differed most markedly from the Slavic population in the incidence of cusp 7 on the lower first and second molars. According to Scott/Turner (1997), the incidence of the cusp 5 on the upper first molar in Western Europe is less frequent, while in Northern Europe its incidence is around 20-40 %. This trait is characteristic for the Sub-Saharan African population (up to 80 %). Scott/Turner (1997) in their work state that the Y groove pattern occurs in early European populations and in India, its incidence ranging from 19 to 27.8 %. The cusp 6 on the first lower molar is considered by Scott/Turner (1997) to be a common trait (more than 30 %). It occurs less frequently only in European populations and in New Guinea (5-15 %). In Northern Europe, the incidence of this trait increases to up to 25 %. Furthermore, Scott and Turner (1997) state that the cusp 7 on the first lower molar is rare worldwide. The only exceptions are the Sub-Saharan African populations, where its frequency is between 25 to 45%. According to the data of Scott and Turner, the Mikulčice population corresponds in the frequency of incidence of dental morphological traits to European groups.

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Table 1. Evaluated dental traits.

Trait	Teeth	Grades
Shoveling	UI1, UI2, UC, LI1, LI2, LC	0-2/3-7
Double shoveling	UI1, UI2, UC, UP1, LI1, LI2	0,1/2-6
Tuberculum dentale	UI1, UI2, UC	0, 1, 2, 3, 4, 5, 6
Interruption groove	UI1, UI2	0, 1, 2, 3, 4
Winging	UI1	1A, 1B, 2, 3, 4
Labial curve	UI1, UI2	0, 1, 2, 3, 4
Canine mesial ridge	UC	0, 1, 2, 3
Canine distal acc. ridge	UC, LC	0, 1, 2, 3, 4, 5
Premolar mesial acc. cusps	UP1, UP2	0, 1
Premolar distal acc. cusps	UP1, UP2	0, 1
Tri-cusped premolars	UP1, UP2	0, 1
Distosagittal ridge	UP1, UP2	0, 1
Metacone	UM1, UM2, UM3	0-2/3-5
Hypocone	UM1, UM2, UM3	0-2/3-5
Metaconule - cusp 5	UM1, UM2, UM3	0, 1, 2, 3, 4, 5
Carabelli's trait	UM1, UM2, UM3	0-3/4-7
Parastyle	UM1, UM2, UM3	0,1/2-6
Premolar lingual cusp	LP1, LP2	A, 0, 1, 2, 3, 4, 5, 6, 7, 8, 9
Fovea anterior	LM1	0, 1, 2, 3, 4
Groove pattern	LM1, LM2, LM3	Y, X, +, other
Cusp number	LM1, LM2, LM3	4, 5, 6
Deflecting wrinkle	LM1, LM2, LM3	0, 1, 2, 3
Medial trigonid crest	LM1, LM2, LM3	0, 1
Distal trigonid crest	LM1, LM2, LM3	0, 1
Protostylid	LM1, LM2, LM3	0/1/ 3-7
Cusp 5 – Hypoconulid	LM1, LM2, LM3	0, 1, 2, 3, 4, 5
Cusp 6 – Entoconulid	LM1, LM2, LM3	0, 1, 2, 3, 4, 5
Cusp 7 – Metaconulid	LM1, LM2, LM3	0, 1, 1A, 2, 3, 4
Peg shaped	UI2, UM3	0, 1
Odontome	UP1, UP2	0, 1
Macrodentes	all teeth	0, 1
Microdentes	all teeth	0, 1
1 – root	all P, M	0, 1
2 – roots	all P, M	0, 1
3 – roots	all P, M	0, 1

Table 2. Mikulčice - Klášteřisko and Kostelisko – incidence of traits and correlation of incidence with sex.
Explanatory notes: ΣN – total number of individuals with the evaluated trait, %- frequency of trait incidence, N – total number of males/females with the evaluated trait, N1 – incidence of trait in males, N2 – incidence of trait in females. Absence of a trait was coded in the protocol as „0“, presence of a trait as „1“, and if the trait could not be evaluated this was coded as „*“

Trait	Sample		Male		Female		χ^2 statistic	
	ΣN	%	N	N1	N	N2	χ2	p=0,05
Shoveling- U1I1	90	43,33	25	5	27	9	1,17	0,2788
Shoveling- U2I2	100	50	31	9	37	18	2,71	0,0996
Shoveling- UC	92	29,35	31	4	32	10	3,07	0,0799
Double shoveling- U1I1	72	8,33	26	1	21	-	0,83	0,3637
Double shoveling- U2I2	91	2,2	30	-	34	-	-	-
Double shoveling- UC	89	6,74	31	-	32	-	-	-
Double shoveling- U1P1	94	23,04	29	5	31	10	1,80	0,1795
Tuberculum dentale U1I1	111	28,83	36	2	37	5	1,33	0,2483
Tuberculum dentale U2I2	119	24,37	42	5	48	12	2,51	0,1133
Tuberculum dentale UC	132	33,33	55	16	45	12	0,07	0,7882
Interruption groove-U1I1-0	91	3,3	31	2	35	1	0,49	0,4841
Interruption groove-U1I1-1	95	6,32	33	1	35	2	0,29	0,5901
Interruption groove-U1I1-2	94	4,26	32	-	35	1	0,93	0,3353
Interruption groove-U1I1-3	95	8,42	32	-	35	1	0,93	0,3353
Interruption groove-U1I1-4	94	14,89	32	4	34	-	4,52	0,0334
Interruption groove-U2I2-0	106	-	-	-	-	-	-	-
Interruption groove-U2I2-1	111	18,02	39	7	44	9	0,08	0,7727
Interruption groove-U2I2-2	110	12,73	39	3	43	5	0,36	0,5486
Interruption groove-U2I2-3	109	5,5	37	1	42	1	0,01	0,9276
Interruption groove-U2I2-4	119	27,73	42	11	46	12	0,00	0,9912
Winging U1I1-11	75	-	31	1	29	1	0,00	0,9617
Winging U1I1-12	74	2,7	31	1	29	-	0,95	0,3294
Winging U1I1-2	74	-	-	-	-	-	-	-
Winging U1I1-3	130	95,38	49	46	54	52	0,33	0,5684
Winging U1I1-4	74	4,05	31	1	29	1	0,00	0,9617
Labial curve U1I1	48	79,17	-	-	-	-	-	-
Canine mesial ridge UC	43	20,93	11	1	12	2	0,29	0,5899
Canine distal acc. ridge UC	58	62,07	13	5	15	12	5,04	0,0248
Premolar mesial acc. cusps U1P1	72	5,56	21	1	21	1	-	-
Premolar mesial acc. cusps U2P2	46	6,52	14	-	16	2	1,88	0,1709
Premolar distal acc. cusps U1P1	75	16	21	3	22	4	0,12	0,7294
Premolar distal acc. cusps U2P2	47	10,64	14	1	16	3	0,87	0,3508
Tricusped premolars U1P1	74	1,35	20	-	23	1	0,89	0,3454
Tricusped premolars U2P2	53	3,77	15	1	21	1	0,06	0,8057
Distosagittal ridge U1P1	53	5,66	16	-	18	2	1,89	0,1693
Distosagittal ridge U2P2	64	-	-	-	-	-	-	-
Metacone U1M1	161	90,68	18	14	33	28	0,40	0,5267
Metacone U2M2	167	96,41	41	39	60	58	0,15	0,6959

Trait	Sample		Male		Female		χ^2 statistic	
	ΣN	%	N	N1	N	N2	χ2	p=0,05
Metacone U3M3	104	91,35	35	31	53	51	1,94	0,1632
Hypocone U1M1	207	98,55	33	33	62	61	0,54	0,4633
Hypocone U2M2	150	72,67	38	27	57	38	0,20	0,6523
Hypocone U3M3	80	53,75	29	12	38	25	3,96	0,0465
Metaconule - cusp 5 U1M1	123	38,21	13	1	26	7	1,97	0,1609
Metaconule - cusp 5 U2M2	103	19,42	24	2	36	4	0,12	0,7253
Metaconule - cusp 5 U3M3	64	17,19	24	5	30	6	0,01	0,9398
Carabelli's trait U1M1	137	34,31	23	4	30	5	0,00	0,9445
Carabelli's trait U2M2	118	1,69	39	1	42	-	1,09	0,2964
Carabelli's trait U3M3	75	2,67	29	1	34	1	0,01	0,9089
Parastyle U1M1	196	0,51	50	-	68	1	0,74	0,3892
Parastyle U2M2	159	2,52	53	3	63	1	1,43	0,2311
Parastyle U3M3	83	1,2	33	-	37	1	0,90	0,3415
Peg shaped U2I2	133	4,51	50	3	54	2	0,30	0,5844
Peg shaped U3M3	106	15,09	43	8	47	7	0,22	0,637
Odontome U1P1	36	0	-	-	-	-	-	-
Odontome U2P2	23	13,04	5	1	8	-	1,73	0,188
Macrodentes U1M1	225	1,57	69	1	93	2	0,11	0,7434
Macrodentes U2M2	189	0,53	63	1	75	-	1,20	0,2735
Macrodentes U3M3	94	2,13	38	-	41	2	1,90	0,1679
Microdentes U1I1	110	0	-	-	-	-	-	-
Macrodentes U1I1	114	7,89	43	2	41	1	0,30	0,585
Macrodentes U2I2	133	3,01	48	-	53	3	2,80	0,0943
Macrodentes UC	179	1,68	72	-	72	1	1,01	0,3156
Macrodentes U1P1	191	1,05	71	-	79	1	0,90	0,3415
Macrodentes U2P2	186	0,54	74	-	82	1	0,91	0,3406
Macrodentes U1M1	225	1,57	69	1	93	2	0,11	0,7434
Macrodentes U2M2	189	0,53	63	1	75	-	1,20	0,2735
Macrodentes U3M3	94	2,13	38	-	41	2	1,90	0,1679
Microdentes U1I1	110	0	-	-	-	-	-	-
Microdentes U2I2	129	1,55	48	2	51	-	2,17	0,1408
Microdentes UC	178	0	-	-	-	-	-	-
Microdentes U1P1	189	0,53	71	1	78	-	1,11	0,293
Microdentes U2P2	184	0,54	74	1	81	0	1,10	0,2939
Microdentes U1M1	252	0,4	68	-	93	1	0,74	0,391
Microdentes U2M2	186	0,54	62	1	74	-	1,20	0,2728
Microdentes U3M3	93	3,23	38	2	41	1	0,43	0,5117
1-Root U1P1	63	79,37	18	8	23	23	16,90	0
2-Root U1P1	50	64	18	16	18	9	6,41	0,0113
3-Root U1P1	30	3,33	11	1	9	-	0,86	0,3534
1-Root U2P2	63	100	-	-	-	-	-	-
2-Root U2P2	30	16,67	8	3	11	1	2,25	0,1337

Trait	Sample		Male		Female		χ^2 statistic	
	ΣN	%	N	N1	N	N2	χ2	p=0,05
3-Root U2P2	27	7,41	6	1	11	1	0,21	0,6432
1-Root U1M1	17	5,88	2	-	10	1	0,22	0,6404
2-Root U1M1	75	6,67	17	-	36	3	1,50	0,2204
3-Root U1M1	124	99,19	34	34	52	52	-	-
1-Root U2M2	43	11,63	13	1	16	-	1,27	0,2589
2-Root U2M2	49	26,53	13	1	21	7	2,93	0,0867
3-Root U2M2	82	95,12	29	29	36	34	1,66	0,1973
1-Root U3M3	33	84,85	11	10	18	15	0,33	0,566
2-Root U3M3	19	52,63	5	2	11	7	0,78	0,377
3-Root U3M3	23	65,22	7	5	11	7	0,12	0,7324

Table 3. Mikulčice - Klášteřisko and Kostelisko – incidence of traits and correlation of incidence with gender. Explanatory notes: ΣN – total number of individuals with the evaluated trait, %- frequency of trait incidence, N – total number of males/females with the evaluated trait, N1 – incidence of trait in males, N2 – incidence of trait in females. Absence of a trait was coded in the protocol as „0“, presence of a trait as „1“, and if the trait could not be evaluated this was coded as „*“

Trait	Sample		Male		Female		χ^2 statistic	
	ΣN	%	N	N1	N	N2	χ^2	p=0,05
Shoveling- L1I1	120	6,67	37	-	46	4	3,38	0,066
Shoveling- L2I2	149	6,71	53	1	63	5	2,15	0,1428
Double shoveling- L1I1	117	-	-	-	-	-	-	-
Canine distal acc. ridge LC	41	46,34	7	2	8	2	0,02	0,876
Premolar lingual acc. cusps L1P1-A	88	5,68	30	2	24	-	1,66	0,1974
Premolar lingual acc. cusps L1P1-0	106	71,7	35	24	35	29	1,94	0,1634
Premolar lingual acc. cusps L1P1-1	91	15,38	33	6	24	4	0,02	0,882
Premolar lingual acc. cusps L1P1-2	90	18,87	29	4	27	4	0,01	0,9131
Premolar lingual acc. cusps L1P1 -3	88	11,36	30	4	24	2	0,34	0,5613
Premolar lingual acc. cusps L1P1-4	85	2,35	29	1	24	-	0,84	0,3584
Premolar lingual acc. cusps L1P1-5	87	3,45	30	2	24	-	1,66	0,1974
Premolar lingual acc. cusps L1P1-6	86	4,65	29	1	24	-	0,84	0,3584
Premolar lingual acc. cusps L1P1-7	85	10,59	29	2	24	3	0,48	0,4873
Premolar lingual acc. cusps L1P1-8	85	-	-	-	-	-	-	-
Premolar lingual acc. cusps L1P1-9	85	-	-	-	-	-	-	-
Premolar lingual acc. cusps L2P2-A	52	3,85	12	-	16	-	-	-
Premolar lingual acc. cusps L2P2 -0	59	47,46	19	10	17	7	0,47	0,4919
Premolar lingual acc. cusps L2P2 -1	53	15,09	12	2	17	4	0,20	0,6532
Premolar lingual acc. cusps L2P2 -2	63	46,03	19	12	18	8	1,30	0,2536
Premolar lingual acc. cusps L2P2 -3	54	18,52	12	4	17	2	1,99	0,1579
Premolar lingual acc. cusps L2P2 -4	51	7,84	12	-	16	1	0,78	0,3778
Premolar lingual acc. cusps L2P2 -5	52	5,77	12	-	16	-	-	-
Premolar lingual acc. cusps L2P2 -6	52	3,85	12	-	17	1	0,73	0,3925
Premolar lingual acc. cusps L2P2 -7	52	1,92	12	-	16	-	-	-

Trait	Sample		Male		Female		χ^2 statistic	
	ΣN	%	N	N1	N	N2	χ^2	p=0,05
Premolar lingual acc. cusps L2P2 -8	52	1,92	12	-	17	1	0,73	0,3925
Premolar lingual acc. cusps L2P2 -9	51	-	-	-	-	-	-	-
Fovea anterior L1M1	55	41,82	1	1	5	1	2,40	0,1213
Groove pattern L1M1-Y	79	81,01	2	-	10	-		
Groove pattern L1M1-+	62	8,06	2	-	7	1	0,32	0,5708
Groove pattern L1M1-X	65	13,85	3	2	6	-	5,14	0,0233
Groove pattern L1M1-4	64	28,13	2	-	6	1	0,38	0,5371
Groove pattern L2M2-Y	85	34,12	20	9	26	7	1,63	0,2019
Groove pattern L2M2 -+	106	72,64	24	16	38	27	0,13	0,7152
Groove pattern L2M2-X	91	47,25	17	7	33	21	2,30	0,1296
Groove pattern L2M2-4	83	10,84	19	3	25	2	0,65	0,42
Groove pattern L3M3-Y	49	24,49	16	3	27	8	0,62	0,4293
Groove pattern L3M3-+	51	33,33	15	3	27	8	0,46	0,4964
Groove pattern L3M3-X	51	50,98	17	9	29	15	0,01	0,9364
Groove pattern L3M3-4	61	65,57	21	17	31	17	3,77	0,0521
Cusp number L1M1-4 cusps	124	14,52	24	7	27	3	2,63	0,105
Cusp number L1M1-5 cusps	156	93,59	31	27	37	34	0,42	0,5169
Cusp number L1M1-6 cusps	122	5,74	24	1	27	-	1,15	0,2841
Cusp number L2M2-4 cusps	181	96,13	54	52	71	71	2,67	0,1021
Cusp number L2M2-5 cusps	130	12,31	39	5	45	3	0,92	0,338
Cusp number L2M2-6 cusps	124	1,61	38	1	43	-	1,15	0,2844
Cusp number L3M3-4 cusps	82	80,49	29	25	42	32	1,09	0,2971
Cusp number L3M3-5 cusps	66	51,52	24	12	33	17	0,01	0,9101
Cusp number L3M3-6 cusps	55	9,09	20	2	29	3	0,00	0,9689
Deflecting wrinkle L1M1	42	40,48	1	-	3	1	0,44	0,505
Deflecting wrinkle L2M2	43	13,95	4	-	9	1	0,48	0,4878
Deflecting wrinkle L3M3	21	9,52	5	-	12	1	0,44	0,5058
Medial trigonid crest L1M1	29	-	4	-	14	1	0,30	0,2523
Medial trigonid crest L2M2	30	-	-	-	-	-	-	-
Medial trigonid crest L3M3	22	4,55	-	-	-	-	-	-
Distal trigonid crest L1M1	30	3,33	-	-	5	1	-	-
Distal trigonid crest L2M2	29	0	-	-	-	-	-	-
Distal trigonid crest L3M3	21	4,76	4	-	14	1	0,30	0,5823
Protostylid L1M1	189	37,57	47	10	55	9	0,40	0,5253
Protostylid L2M2	179	32,4	57	11	67	21	2,33	0,1266
Protostylid L3M3	84	17,86	37	9	38	3	3,77	0,0524
Cusp 5 L1M1	143	93,71	28	23	26	23	0,43	0,5137
Cusp 5 L2M2	109	13,76	29	4	36	3	0,50	0,4803
Cusp 5 L3M3	69	47,83	28	14	32	14	0,23	0,6283
Cusp 6 L1M1	110	4,55	20	-	19	1	1,08	0,2986
Cusp 6 L2M2	106	1,89	30	1	34	0	1,15	0,2833
Cusp 6 L3M3	58	8,62	23	2	29	3	0,04	0,8412

Trait	Sample		Male		Female		χ^2 statistic	
	ΣN	%	N	N1	N	N2	χ^2	p=0,05
Cusp 7 L1M1	109	1,83	21	1	19	-	0,93	0,3354
Cusp 7 L2M2	107	-	23	-	29	1	0,81	0,3685
Cusp 7 L3M3	58	-	-	-	-	-	-	-
Macrodentes L1I1	142	0,7	50	1	53	-	1,07	0,3009
Macrodentes L2I2	176	-	76	-	87	-	-	-
Macrodentes LC	217	-	-	-	-	-	-	-
Macrodentes L1P1	211	0,47	76	-	87	0	-	-
Macrodentes L2P2	168	0,6	56	-	78	0	-	-
Macrodentes L1M1	209	1,44	59	-	64	1	0,93	0,335
Macrodentes L2M2	196	0,51	70	-	72	1	0,98	0,3224
Macrodentes L3M3	93	-	-	-	-	-	-	-
Microdentes L1I1	142	2,82	50	1	53	2	0,29	0,5927
Microdentes L2I2	176	0,57	69	-	70	1	0,99	0,319
Microdentes LC	217	0	-	-	-	-	-	-
Microdentes L1P1	210	0	-	-	-	-	-	-
Microdentes L2P2	168	0	-	-	-	-	-	-
Microdentes L1M1	208	0,96	59	-	62	1	0,96	0,3273
Microdentes L2M2	196	1,02	71	-	71	2	2,03	0,1544
Microdentes L3M3	94	4,26	39	-	45	4	3,64	0,0564
1-Root L1P1	62	100	-	-	-	-	-	-
2-Root L1P1	31	-	-	-	-	-	-	-
3-Root L1P1	31	-	-	-	-	-	-	-
1-Root L2P2	64	100	-	-	-	-	-	-
2-Root L2P2	25	8	5	-	9	1	0,60	0,4392
3-Root L2P2	24	-	-	-	-	-	-	-
1-Root L1M1	54	3,7	12	-	17	-	-	-
2-Root L1M1	94	98,94	20	20	34	34	-	-
3-Root L1M1	54	-	-	-	-	-	-	-
1-Root L2M2	49	26,53	12	2	16	4	0,28	0,5949
2-Root L2M2	70	90	18	17	22	20	0,18	0,6428
3-Root L2M2	44	2,27	11	-	15	1	0,76	0,3825
1-Root L3M3	13	46,15	3	-	6	5	5,63	0,0177
2-Root L3M3	22	95,45	7	7	10	10	-	-
3-Root L3M3	12	25	5	2	3	1	0,04	0,8504

Table 4. Interpopulation comparison: Mikulčice (Klášteřisko and Kostelisko) – modern Czechoslovak population (Krchová et al. 2007).

Trait	Mikulčice		Czech rep.		χ^2 statistic		Yates' correction	
	N	%	N	%	χ^2	p-level	χ^2	p-level
Shoveling- U1I1	90	43,33	143	1,4	66,99	0,0000	64,13	0,0000
Shoveling- U2I2	100	50	130	-	83,06	0,0000	80,14	0,0000
Shoveling- UC	92	29,35	97	-	33,21	0,0000	30,86	0,0000

Trait	Mikulčice		Czech rep.		χ^2 statistic		Yates' correction	
	N	%	N	%	χ^2	p-level	χ^2	p-level
Double shoveling- U1I1	72	8,33	147	10,2	0,20	0,6587	0,04	0,8435
Double shoveling- U2I2	91	2,2	133	3,01	0,14	0,7124	0,00	0,9580
Double shoveling- UC	89	6,74	97	-	6,76	0,0093	4,77	0,0290
Double shoveling- U1P1	94	23,04	116	-0	30,33	0,0000	27,88	0,0000
Tuberculum dentale UC	132	33,33	98	63,27	20,28	0,0000	19,09	0,0000
Canine distal acc. ridge UC	58	62,07	95	84,21	9,63	0,0019	8,46	0,0036
Premolar mesial acc. cusps U2P2	46	6,52	84	5,95	0,02	0,8972	0,06	0,8007
Premolar distal acc. cusps U2P2	47	10,64	74	17,57	1,09	0,2965	0,61	0,4343
Premolar tricusps U2P2	53	3,77	90	2,22	0,30	0,5869	0,00	0,9854
Distosagittal ridge U2P2	64	-	88	-	-	-	-	-
Metacone U1M1	161	90,68	194	100	18,87	0,0000	16,64	0,0000
Metacone U2M2	167	96,41	82	98,78	1,13	0,2870	0,43	0,5113
Metacone U3M3	104	91,35	7	100	0,66	0,4168	0,01	0,9230
Hypocone U1M1	207	98,55	199	100	2,91	0,0883	1,27	0,2606
Hypocone U2M2	150	72,67	58	67,74	0,60	0,4386	0,36	0,5460
Cusp 5 - U1M1	123	38,21	139	50,36	3,90	0,0484	3,42	0,0644
Cusp 5 - U2M2	103	19,42	42	23,81	0,35	0,5537	0,13	0,7142
Cusp 5 U3M3	64	17,19	2	-	0,41	0,5207	0,10	0,7481
Carabelli's trait U1M1	137	34,31	176	38,07	0,47	0,4927	0,32	0,5702
Carabelli's trait U2M2	118	1,69	59	-	1,01	0,3146	0,06	0,8015
Carabelli's trait U3M3	75	2,67			-	-	-	-
Parastylus 1M1	196	0,51	164	0,61	0,02	0,8993	0,34	0,5583
Parastylus 2M2	159	2,52	65	1,54	0,20	0,6532	0,00	0,9610
Parastylus 3M3	83	1,2	2	-	0,02	0,8759	10,00	0,0016
Shoveling- L1I1-0	120	6,67	175	9,71	0,85	0,3559	0,5	0,4774
Shoveling- L2I2-0	149	6,71	152	10,53	1,39	0,2388	0,95	0,3307
Canine distal acc. ridge LC	41	46,34	84	17,86	11,29	0,0008	9,9	0,0017
Fovea anterior L1M1	55	41,82	107	75,7	18,15	-	16,7	-
Groove pattern L1M1-Y	79	81,01	65	72,31	1,53	0,2162	1,08	0,2995
Groove pattern L2M2-Y	85	34,12	19	5,26	6,3	0,0121	4,97	0,0258
Groove pattern L3M3-Y	49	24,49	1	100	2,9	0,0883	0,31	0,5805
Cusp number L1M1-4 cusps	124	14,52	140	12,86	0,15	0,695	0,05	0,8318
Cusp number L1M1-5 cusps	156	93,59	153	92,16	0,24	0,6243	0,07	0,7883
Cusp number L1M1-6 cusps	122	5,74	137	5,84	-	0,9721	0,05	0,8169
Cusp number L2M2-4 cusps	181	96,13	55	98,18	0,54	0,4621	0,1	0,7565
Cusp number L2M2-5 cusps	130	12,31	26	7,69	0,45	0,5013	0,11	0,7367
Cusp number L2M2-6 cusps	124	1,61	26	-	0,43	0,5144	0,08	0,7731
Cusp number L3M3-4 cusps	82	80,49	2	-	7,51	0,0061	3,49	0,0617
Cusp number L3M3-5 cusps	66	51,52	1	-	1,05	0,3065	-	0,9880
Cusp number L3M3-6 cusps	55	9,09	1	-	0,1	0,752	2,11	0,1461
Deflecting wrinkle L1M1	42	40,48	72	8,33	17,02	-	15,08	0,0001
Distal trigonid crest L1M1	30	3,33	82	-	2,69	0,1009	0,26	0,6082

Trait	Mikulčice		Czech rep.		χ^2 statistic		Yates' correction	
	N	%	N	%	χ^2	p-level	χ^2	p-level
Protostylid L1M1	189	37,57	161	27,33	4,13	0,0421	3,68	0,0551
Protostylid L2M2	179	32,4	65	20	3,56	0,0594	2,98	0,0843
Protostylid L3M3	84	17,86	3	-	0,65	0,4211	-	0,9786
Cusp 5 L1M1	143	93,71	159	93,71	-	0,9987	0,06	0,8136
Cusp 5 L2M2	109	13,76	35	11,43	0,13	0,7227	-	0,9460
Cusp 5 L3M3	69	47,83	-	-	-	-	-	-
Cusp 6 L1M1	110	4,55	91	8,79	1,48	0,2231	0,87	0,3523
Cusp 6 L2M2	106	1,89	33	-	0,63	0,4267	-	0,9664
Cusp 6 L3M3	58	8,62			-	-	-	-
Cusp 7 L1M1	109	1,83	132	6,82	3,4	0,0651	2,36	0,1248
Cusp 7 L2M2	107	-	39	-	-	-	-	-
Cusp 7 L3M3	58	-	2	-	-	-	-	-

Table 5. Interpopulation comparison: Mikulčice (Klášteřisko and Kostelisko) – population from the period of Roman Empire (Manzi et al. 1997). Explanatory notes: Roman population from the village of Lucus Feroniae and the city of Portus Romae (the Isola Sacra burial site).

Trait	Mikulčice		Rome period		χ^2 statistic		Yates' correction	
	N	%	N	%	χ^2	p-level	χ^2	p-level
Shoveling- U1I1	90	43,33	28	10,71	9,91	0,0016	8,54	0,0035
Shoveling- U2I2	100	50	28	28,57	4,05	0,0442	3,23	0,0721
Double shoveling- U1I1	72	8,33	38	7,89	0,01	0,9203	0,08	0,7749
Double shoveling- U2I2	91	2,2	50	-	1,11	0,2921	0,10	0,7555
Tuberculum dentale UC	132	33,33	87	65,52	21,86	0,0000	20,58	0,0000
Canine distal acc. ridge UC	58	62,07	25	56	0,27	0,6033	0,08	0,7842
Hypocone U1M1	207	98,55	102	100	1,49	0,2222	0,37	0,5452
Hypocone U2M2	150	72,67	89	79,78	1,52	0,2176	1,16	0,2815
Cusp 5 - U1M1	123	38,21	69	4,35	26,32	0,0000	24,59	0,0000
Cusp 5 - U2M2	103	19,42	71	18,81	0,03	0,8625	0,00	0,9892
Cusp 5 U3M3	64	17,19	59	23,73	0,81	0,3681	0,46	0,4988
Carabelli's trait U1M1	137	34,31	64	25	1,76	0,1846	1,35	0,2453
Carabelli's trait U2M2	118	1,69	82	6,1	2,78	0,0954	1,63	0,2023
Carabelli's trait U3M3	75	2,67	68	13,24	5,61	0,0179	4,22	0,0399
Parastylus 1M1	196	0,51	74	6,76	9,65	0,0019	6,99	0,0082
Parastylus 2M2	159	2,52	104	-	2,66	0,1029	1,24	0,2650
Parastylus 3M3	83	1,2	73	1,37	0,01	0,9203	0,39	0,5341
Shoveling- L1I1-0	120	6,67	26	-	1,83	0,1761	0,77	0,3794
Shoveling- L2I2-0	149	6,71	53	3,77	0,6	0,4386	0,19	0,6608
Canine distal acc. ridge LC	41	46,34	47	10,64	14,07	0,0002	12,33	0,0004
Fovea anterior L1M1	55	41,82	13	76,92	5,19	0,0227	3,88	0,0489
Groove pattern L1M1-Y	79	81,01	65	80	0,02	0,8875	0,00	0,9531
Groove pattern L2M2-Y	85	34,12	110	23,64	2,6	0,1069	2,11	0,1464
Groove pattern L3M3-Y	49	24,49	82	14,63	1,99	0,1583	1,39	0,2389

Trait	Mikulčice		Rome period		χ^2 statistic		Yates' correction	
	N	%	N	%	χ^2	p-level	χ^2	p-level
Deflecting wrinkle L1M1	42	40,48	45	2,22	19,37	0,0000	17,11	0,0000
Distal trigonid crest L1M1	30	3,33	52	-	1,75	0,1859	0,08	0,7793
Protostylid L1M1	189	37,57	65	1,54	30,91	0,0000	29,16	0,0000
Protostylid L2M2	179	32,4	83	10,84	13,85	0,0002	12,74	0,0004
Protostylid L3M3	84	17,86	67	47,76	15,55	0,0001	14,18	0,0002
Cusp 5 L1M1	143	93,71	84	89,29	1,42	0,2334	0,88	0,3494
Cusp 5 L2M2	109	13,76	110	7,27	2,45	0,1175	1,81	0,1784
Cusp 5 L3M3	69	47,83	82	39,02	1,18	0,2774	0,85	0,3559
Cusp 6 L1M1	110	4,55	82	-	3,83	0,0503	2,24	0,1341
Cusp 6 L2M2	106	1,89	110	-	2,09	0,1483	0,54	0,4612
Cusp 6 L3M3	58	8,62	80	3,75	1,46	0,2269	0,70	0,4011
Cusp 7 L1M1	109	1,83	95	3,16	0,37	0,5430	0,02	0,8762
Cusp 7 L2M2	107	-	112	1,79	1,93	0,1648	0,46	0,4977
Cusp 7 L3M3	58	-	82	-	-	-	-	-

Table 6. Interpopulation comparison: Mikulčice (Klášteřisko and Kostelisko) – the population from the period of the settlement of Greenland (OG) (Scott et al. 1992).

Trait	Mikulčice		OG		χ^2 statistic		Yates' correction	
	N	%	N	%	χ^2	p-level	χ^2	p-level
Metacone U1M1	135	39,26	32	71,9	11,1	0,0009	9,82	0,0017
Metacone U2M2	145	54,48	45	77,8	7,77	0,0053	6,82	0,0090
Metacone U3M3	74	25,68	47	25,5	-	1,0000	0,04	0,8446
Hypocone U1M1	202	93,07	43	93	-	1,0000	0,10	0,7492
Hypocone U2M2	150	72,67	42	88,1	4,29	0,0383	3,48	0,0620
Cusp 5 - U1M1	123	38,21	19	21,1	2,11	0,1463	1,43	0,2325
Cusp 5 - U2M2	103	19,42	33	36,4	3,99	0,0458	3,10	0,0782
Cusp 5 U3M3	64	17,19	36	36,1	4,52	0,0335	3,55	0,0597
Parastylus 1M1	196	0,51	15	6,7	5,62	0,0178	0,98	0,3225
Parastylus 2M2	159	2,52	23	8,7	2,41	0,1206	0,86	0,3540
Parastylus 3M3	83	1,2	21	9,5	4,14	0,0419	1,70	0,1919
Peg shaped 3M3	106	15,09	20	-	3,46	0,0629	2,23	0,1353
1-2 root 2M2	51	35,29	30	43,3	0,52	0,4708	0,23	0,6297
Groove pattern Y L1M1	79	81,01	48	92,3	2,66	0,1029	1,89	0,1689
Groove pattern Y L2M2	85	34,12	48	33,3	0,01	0,9203	0,01	0,9212
Groove pattern Y L3M3	49	24,49	49	24,5	-	1,0000	0,06	0,8143
Deflecting wrinkle 1M1	42	40,48	7	42,9	0,01	0,9203	0,09	0,7667
Protostylid L1M1	189	37,57	18	16,7	3,13	0,0769	2,28	0,1309
Protostylid L2M2	179	32,4	26	15,4	3,12	0,0773	2,36	0,1243
Protostylid L3M3	84	17,86	27	40,7	5,97	0,0146	4,76	0,0292
Cusp 5 L1M1	143	93,71	24	83,3	3,08	0,0793	1,80	0,1791
Cusp 5 L2M2	109	13,76	44	15,9	0,12	0,7290	0,01	0,9297
Cusp 5 L3M3	69	47,83	51	49	0,02	0,8875	0,00	0,9558

Trait	Mikulčice		OG		χ² statistic		Yates' correction	
	N	%	N	%	χ^2	p-level	χ^2	p-level
Cusp 6 L1M1	110	4,55	19	26,3	10,74	0,0010	7,91	0,0049
Cusp 6 L2M2	106	1,89	40	2,5	0,05	0,8231	0,18	0,6737
Cusp 6 L3M3	58	8,62	47	19,2	2,49	0,1146	1,66	0,1973
Cusp 7 L1M1	109	1,83	29	17,2	11,29	0,0008	8,32	0,0039
Cusp 7 L2M2	107	-	40	20	22,63	0,0000	18,91	0,0000
Cusp 7 L3M3	58	-	31	25,8	-	-	-	-
3- roots 1M1	54	-	12	-	-	-	-	-
1-root 2M2	49	26,53	27	29,6	0,08	0,7773	0,00	0,9831

Table 7. Interpopulation comparison: Mikulčice- Klášteřisko and Kostelisko – the Middle Ages population of Norway (NOR) (Scott et al. 1992).

Trait	Mikulčice		NOR		χ² statistic		Yates' correction	
	N	%	N	%	χ^2	p-level	χ^2	p-level
Metacone U1M1	135	39,26	67	59,7	7,53	0,0061	6,73	0,0095
Metacone U2M2	145	54,48	83	69,9	5,22	0,0223	4,60	0,0321
Metacone U3M3	74	25,68	64	31,3	0,53	0,4666	0,29	0,5922
Hypocone U1M1	202	93,07	75	96	0,82	0,3652	0,39	0,5344
Hypocone U2M2	150	72,67	83	85,5	5,04	0,0248	4,33	0,0373
Hypocone U3M3	80	53,75	59	49,2	0,29	0,5902	0,13	0,7155
Cusp 5 - U1M1	123	38,21	49	20,4	5,01	0,0252	4,24	0,0395
Cusp 5 - U2M2	103	19,42	55	25,5	0,77	0,3802	0,46	0,4988
Cusp 5 U3M3	64	17,19	44	22,7	0,51	0,4751	0,22	0,6403
Parastylus 1M1	196	0,51	81	-	0,41	0,5220	0,21	0,6475
Parastylus 2M2	159	2,52	78	2,6	0,00	1,0000	0,17	0,6761
Parastylus 3M3	83	1,2	54	1,9	0,10	0,7518	0,18	0,6743
Peg shaped 3M3	106	15,09	71	2,8	7,02	0,0081	5,74	0,0166
2-roots 1P1	50	64	64	43,8	4,62	0,0316	3,84	0,0500
1-2 root 2M2	51	35,29	78	35,9	0,00	1,0000	0,01	0,9060
Groove pattern Y L1M1	79	81,01	52	94,2	4,62	0,0316	3,57	0,0587
Groove pattern Y L2M2	85	34,12	72	19,4	4,22	0,0399	3,51	0,0608
Groove pattern Y L3M3	49	24,49	56	14,3	1,76	0,1840	1,16	0,2804
Deflecting wrinkle 1M1	42	40,48	26	19,2	3,31	0,0688	2,41	0,1204
Protostylid L1M1	189	37,57	34	2,9	15,80	0,0001	14,26	0,0002
Protostylid L2M2	179	32,4	44	2,3	16,48	0,0000	14,97	0,0001
Protostylid L3M3	84	17,86	34	20,6	0,12	0,7301	0,01	0,9330
Cusp 5 L1M1	143	93,71	50	90	0,76	0,3845	0,31	0,5803
Cusp 5 L2M2	109	13,76	67	9	0,91	0,3395	0,51	0,4742
Cusp 5 L3M3	69	47,83	55	45,5	0,07	0,7926	0,01	0,9348
Cusp 6 L1M1	110	4,55	38	10,5	1,77	0,1835	0,88	0,3491
Cusp 6 L2M2	106	1,89	80	-	1,53	0,2167	0,27	0,6050
Cusp 6 L3M3	58	8,62	44	4,6	0,65	0,4201	0,17	0,6812

Trait	Mikulčice		NOR		χ² statistic		Yates' correction	
	N	%	N	%	χ^2	p-level	χ^2	p-level
Cusp 7 L1M1	109	1,83	52	13,5	9,02	0,0027	6,95	0,0084
Cusp 7 L2M2	107	-	63	11,1	12,40	0,0004	9,74	0,0018
Cusp 7 L3M3	58	-	44	18,2	-	-	-	-
3- roots 1M1	54	-	44	-	-	-	-	-
1-root 2M2	49	26,53	86	23,3	0,18	0,6703	0,05	0,8278

Table 8. Interpopulation comparison: Mikulčice- Klášteřisko and Kostelisko – Middle Ages population of Greenland (SvG) (Scott et al. 1992).

Trait	Mikulčice		SvG		χ² statistic		Yates' correction	
	N	%	N	%	χ^2	p-level	χ^2	p-level
Metacone U1M1	135	39,26	15	53,3	1,11	0,2921	0,60	0,4379
Metacone U2M2	145	54,48	28	71,4	2,75	0,0973	2,10	0,1469
Metacone U3M3	74	25,68	22	13,6	1,39	0,2384	0,79	0,3731
Hypocone U1M1	202	93,07	21	100	1,55	0,2131	0,60	0,4392
Hypocone U2M2	150	72,67	30	76,7	0,2	0,6547	0,05	0,8211
Cusp 5 - U1M1	123	38,21	11	54,6	1,13	0,2878	0,55	0,4595
Cusp 5 - U2M2	103	19,42	24	41,7	5,34	0,0208	4,18	0,0409
Cusp 5 U3M3	64	17,19	19	36,8	3,33	0,0680	2,28	0,1314
Parastylus 1M1	196	0,51	15	-	0,08	0,7773	2,80	0,0943
Parastylus 2M2	159	2,52	20	10	3,07	0,0797	1,20	0,2742
Parastylus 3M3	83	1,2	16	6,3	1,72	0,1897	0,12	0,7316
Peg shaped 3M3	106	15,09	10	-	1,75	0,1859	0,71	0,3989
1-2 root 2M2	51	35,29	20	65	5,15	0,0232	4,02	0,0450
Groove pattern Y L1M1	79	81,01	15	73,3	0,46	0,4976	0,11	0,7427
Groove pattern Y L2M2	85	34,12	33	30,3	0,16	0,6892	0,03	0,8592
Groove pattern Y L3M3	49	24,49	26	26,9	0,05	0,8231	0,00	0,9614
Deflecting wrinkle 1M1	42	40,48	10	30	0,37	0,5430	0,06	0,8023
Protostylid L1M1	189	37,57	11	9,1	3,66	0,0557	2,53	0,1119
Protostylid L2M2	179	32,4	17	11,8	3,11	0,0778	2,22	0,1365
Protostylid L3M3	84	17,86	18	5,6	1,7	0,1923	0,89	0,3445
Cusp 5 L1M1	143	93,71	16	100	1,07	0,3009	0,21	0,6435
Cusp 5 L2M2	109	13,76	23	32	3,8	0,0513	2,70	0,1006
Cusp 5 L3M3	69	47,83	26	53,9	10,71	0,0011	9,01	0,0027
Cusp 6 L1M1	110	4,55	13	23,1	6,57	0,0104	3,87	0,0491
Cusp 6 L2M2	106	1,89	24	8,3	2,73	0,0985	0,99	0,3188
Cusp 6 L3M3	58	8,62	24	16,7	1,12	0,2899	0,45	0,5014
Cusp 7 L1M1	109	1,83	18	38,9	32,21	0,0000	26,83	0,0000
Cusp 7 L2M2	107	-	22	4,6	22,63	0,0000	18,91	0,0000
Cusp 7 L3M3	58	-	21	9,5	-	-	-	-
3- roots 1M1	54	-	21	-	-	-	-	-
1-root 2M2	49	26,53	30	26,7	-	1,0000	0,06	0,8033

List of Some Abbreviations

Acc. Chem. Res.	Accounts of Chemical Research
Acta Anat.	Acta Anatomica
Acta Chir. Plast.	Acta Chirurgiae Plasticae
Acta Med.Lituan.	Acta Medica Lituanica
Acta Musei Nationalis Pragae. B, Hist. Naturalis	Acta Musei Nationalis Pragae, Series B, Historia Naturalis
Acta Rer. Natur. Mus. Nat. Slov.	Acta Rerum Naturalium Musei Nationalis Slovaci, Bratislava
Acta Zoologica Fennica	Acta Zoologica Fennica (Societas pro Fauna et Flora Fennica)
Am. J. Clin. Pathol.	American Journal of Clinical Pathology
Am. J. Hum. Biol. -	American Journal of Human Biology: the official journal of the Human Biology Council
Am. J. Dis. Child.	American Journal of Diseases of Children
Am. J. Hum. Genet.	American Journal of Human Genetics
Am. J. Infect. Dis.	American Journal of Infectious Diseases
Am. J. Med. Genet.	American Journal of Medical Genetics
Am. J. Phys. Anthropol.	American Journal Physical Anthropology
Am. J. Orthod. Dentofacial. Orthop.	American Journal of Orthodontics and Dentofacial Orthopedics: official publication of the American Association of Orthodontists, its constituent societies, and the American Board of Orthodontics
Anthropol. Anz.	Anthropologischer Anzeiger; Bericht über die biologisch-anthropologische Literatur
Anthropol. Sci.	Anthropological Science: Journal of the Anthropological Society of Nippon
Anat. Rec.	Anatomical Record
Anc. Biomol.	Ancient Biomolecules
Ann. Hum. Biol.	Annals of Human Biology
Annu. Rev. Ecol. Syst.	Annual Review of Ecology and Systematics
Anc. Biomol.	Ancient Biomolecules
Ann. Med. Leg. Criminol. Police Sci. Toxicol	Annales de médecine légale, criminologie, police scientifique et toxicologie
Antrop. Port.	Antropologia portuguesa
Arch. Hist.	Archaeologia historica
Arch. Rozhledy	Archeologické rozhledy
Aust. Dent. J.	Australian Dental Journal
Bull. Mém. Soc. Anthrop.	Les Bulletins et Mémoires de la Société d'Anthropologie de Paris
Bull. Slov. Antrop. Spol.	Bulletin Slovenskej antropologickej společnosti SAV
Br. J. Psychol.	The British Journal of Psychology
Br. J. Radiol.	The British Journal of Radiology
Calcif. Tissue Int.	Calcified Tissue International
Caries Res.	Caries Research
Cleft Palate Craniofac. J.	The Cleft Palate-Craniofacial Journal : official publication of the American Cleft Palate-Craniofacial Association
Clin. Anat.	Clinical Anatomy
Clin. Chem.	Clinical Chemistry
C. R. Palevol	Comptes Rendus Palevol

Coll. Antropol.	Collegium Antropologicum
Contrib. Biol. Geol.	Contributions in Biology and Geology
Čas. Nár. muz., ř. přírodovědná	Časopis Národního muzea, řada přírodovědná
Český Čas. Hist.	Český časopis historický
Dent. Antropol.	Dental Anthropology, A publication of the dental antropology association
Dtsch. Z. Gesamte Gerichtl. Med.	Deutsche Zeitschrift für die gesamte gerichtliche Medizin
Econ. Hum. Biol.	Economics and Human Biology
Eur. J. Archaeol.	European Journal of Archaeology
Eur. J. Morphol.	European Journal of Morphology
Eur. J. Epidemiol.	European Journal of Epidemiology
Eur. J. Orthod.	European Journal of Orthodontics
Evolution	Evolution; international journal of organic evolution
Forensic Sci. Int.	Forensic Science International
Geochim. Cosmochim. Acta	Geochimica et Cosmochimica Acta. Journal of The Geochemical Society and The Meteoritical Society
Homo	Homo - Journal of Comparative Human Biology
Hum. Biol.	Human Biology
J. Hum. Evol.	Journal of Human Evolution
Int. J. Legal Med.	International Journal of Legal Medicine
Int. J. Osteoarchaeol.	International Journal of Osteoarchaeology
Jahrb. RGZM	Jahrbuch des Römisch-Germanischen Zentralmuseums Mainz
J. Archaeol. Sci.	Journal of Archaeological Science
J. Anat.	Journal of Anatomy
J. Bone Miner. Res.	Journal of Bone and Minerál Research: the official journal of the American Society for Bone and Mineral Research
J. Bone Point. Surg.	Journal of Bone and Joint Surgery
J. Clin. Densitom.	Journal of Clinical Densitometry : the official journal of the International Society for Clinical Densitometry
J. Craniofac. Genet. Dev. Biol.	Journal of Craniofacial Genetics and Developmental Biology
J. Dent. Res.	Journal of Dental Research
Epidemiol. Community Health	Epidemiology and Community Health
J. Forensic Sci.	Journal of Forensic Science
Am. J. Hum. Biol.	American Journal of Human Biology
J. Hum. Ecol.	Journal of Human Ecology
J. Hum. Evol.	Journal of Human Evolution
J. Infect Dis.	Journal of Infectious Diseases
J. Orthop. Res.	Journal of Orthopaedic Research: official publication of the Orthopaedic Research Society
J. R. Anthropol. Inst.	The Journal of the Royal Anthropological Institute
Malays. J. Pathol.	The Malaysian Journal of Pathology
Med. Sci. Law	Medicine, Science, and the Law
Med. Radiogr. Photogr.	Medical Radiography and Photography
Mitt. Bln. Ges. Anthrop. Ethnol. Urgesch.	Mitteilungen der Gesellschaft für Anthropologie, Ethnologie und Urgeschichte
Nucleic Acids Res.	Nucleic Acids Research
Ossa	Ossa: International Journal of Skeletal Research
Pam. Arch.	Památky Archeologické
Paleopathology Club	Newsletter
Paleopathol. Newsl.	Paleopathology Newsletter
Philos. Trans. R. Soc. Lond., B, Biol. Sci.	Philosophical transactions of the Royal Society of London. Series B, Biological Sciences
Pravěk NŘ	Pravěk Nová Řada
Proc. Natl. Acad. Sci. U.S.A.	Proceedings of the National Academy of Sciences of the United States of America
Proc. Nutr. Soc.	The Proceedings of the Nutrition Society

Proc. R. Soc. Lond., B, Biol. Sci.	Proceedings of the Royal Society of London. Series B, Containing papers of a Biological character.
Przegl. Antropol.	Przeglad Antropologiczny (at present: Anthropological Review)
Rev. Phys. Anthrop.	Revue Physique d'Anthropologie ??
Sborník Prací Fil. Fak. Brno	Sborník prací Filosofické fakulty brněnské univerzity
Slovenská Arch.	Slovenská archeológia
World Arch.	World Archaeologie
Yearb. Phys. Anthropol.	Yearbook of Physical Anthropology
Z. Morphol. Anthropol.	Zeitschrift für Morphologie und Antropologie

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Herausgegeben von Petr Velemínský und Lumír Poláček

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