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Topography of the mandibular canal in male human skulls originating from different time periods

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Background: *Dynamic advances in dentistry, especially in implantology has inspired researchers to carry out many studies investigating the topography of the mandibular canal and its ethnic differences. The aim of the study was a comparative analysis of variations in the position and topography of the mandibular canal based on radiographic images of human mandibles originating from modern and medieval skulls.*

Materials and methods: *Morphometric examination of 126 radiographs of skulls (92 modern and 34 medieval skulls) was included. The age and sex of individuals were determined based on the morphology of the skull, the obliteration of cranial sutures, and the degree of tooth wear. To define the topography of the mandibular canal on X-ray images, we took 8 anthropometric measurements.*

Results: *We observed significant differences in several parameters. The distance between the base of the mandible and the bottom of the mandibular canal, the distance between the top of the mandibular canal and the crest of the alveolar arch, and the height of the mandibular body. Significant asymmetry was found for two parameters of mandibles from modern skulls: the distance between the top of the mandibular canal and the crest of the alveolar arch at the level of the second molar ($p < 0.05$), and the distance between the mandibular foramen and the margin of the anterior mandibular ramus ($p < 0.007$). There were no significant differences between measurements taken on the right and left sides of the medieval skulls.*

Conclusions: *Our study revealed differences in the position of the mandibular canal between modern and medieval skulls, confirming the presence of geographical and chronological differences between populations. Knowledge of variability in the position of the mandibular canal between different local populations is fundamental for the correct interpretation of findings from diagnostic radiological studies used in dental practice and in forensic odontology or analysis of archaeological bone materials.* (Folia Morphol 2024; 83, 1: 168–175)

Keywords: mandibular canal, palaeoanthropology, anatomy, mental foramen, asymmetry

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INTRODUCTION

The mandibular canal, nowadays referred to as the inferior alveolar (nerve) canal [29, 36, 63], is located in the spongy bone of the mandible and is available for diagnosis only by imaging techniques using X-rays [1, 3, 8, 20–22, 29, 32, 66]. Panoramic images acquired with classical and digital techniques, or increasingly popular computed tomography are clinically relevant [3, 8, 43, 67]. Panoramic radiography is part of the standard dental diagnostics procedure performed before planning treatment. Acquired radiograms allow for the evaluation of dentition in terms of periapical inflammatory lesions, periodontitis, root position before tooth extraction, and the position of impacted teeth [3, 12, 57, 58, 64, 65]. They are also useful for the diagnosis of pathologies within the temporomandibular joint [48] or maxillary sinuses [16, 23, 25]. Radiographic evaluation is also necessary before treatment involving implant placement. It allows for the assessment of the volume and quality of the preserved bone of the maxillary alveolar process, the mandibular corpus, and the alveolar part of the mandible [32]. It visualises the position of important anatomical structures such as the bottom of the nasal cavity or maxillary sinus, and the topography of the mandibular canal with the position of the mental foramen [16, 17, 36, 43, 52, 57, 59, 64, 65]. Dynamic advances in dental implantology as well as prosthetics have inspired researchers to carry out many studies investigating the topography of the mandibular canal in terms of its position in relation to the base of the mandible and the apical parts of tooth roots [43, 57, 67]. Other studies have analysed the position of the mental foramen and the presence of the loop of the mental nerve [33, 50, 51, 57, 58], and the presence of the incisive canal [30] or bifid accessory canals [17, 41, 63, 62]. Studies in this area provide clinically relevant information which is extremely valuable for planning and performing treatments.

In the evolution leading to the emergence of *Homo sapiens*, the size and massiveness of the hominin facial skeleton has reduced, and its position in relation to the brain case has changed from the protruding face to retracted in the anterior region of the skull base [27, 38]. Archaeological studies have revealed certain trends that can be observed in the structure of the *Homo sapiens* skull, such as brachycephalization and gracilization combined with a reduction in the size of the facial skeleton attributed to the change in the life model of ancient human populations that shifted from hunting and gathering to a more sedentary lifestyle due to the development of agriculture [19, 31, 46, 47, 62].

The shape and size of the teeth over thousands of years of the existence of the human species did not change much, although the above-mentioned trends were accompanied by a slight reduction in the size of molars [5]. The formation of dentition in humans is generally regarded as very strongly determined by genetic factors, in contrast to the facial skeleton, which is characterized by high plasticity [34, 56]. This means that changing environmental conditions have a much stronger impact on the developing facial skeleton than on teeth formation [34, 56]. The aforementioned differences between the teeth and the facial skeleton in response to environmental factors can be interpreted as the main cause of tooth crowding, which is increasingly frequent in modern populations [62]. Thus, the reduction in the size of the maxilla and the mandible can lead to crowding of the teeth [66], especially in the anterior region. Another observed trend is the reduction in the number of teeth in the dental arch and impaction of teeth which mainly concerns third molars, also called wisdom teeth, within the alveolar process [24, 42], which is also important when planning dental treatment.

One reason for this is the development of civilization, which leads to changes in diet and the texture of ingested food. An increasing number of food products are processed and disintegrated, which influences the formation of the mandible [7, 26, 40, 68]. Studies carried out on the mandibles from different historical periods as well as modern ones have identified variability in the position of the mental foramen in different ethnic groups, which may be related to the differences in the topography of the mandibular canal [1, 4, 5, 15, 20, 22, 27, 31, 34, 37]. Information on the detailed anatomy and topography of the mandibular structures may be important not only in dental practice, but also for the analysis of archaeological material or in forensic medicine.

The aim of the study was to comparative analysis of variations in the position and topography of the mandibular canal based on radiographic images of human mandibles originating from modern and medieval skulls.

MATERIALS AND METHODS

Study material

— 92 modern human skulls dated to the beginning of the 20th century, kept in the museum collections

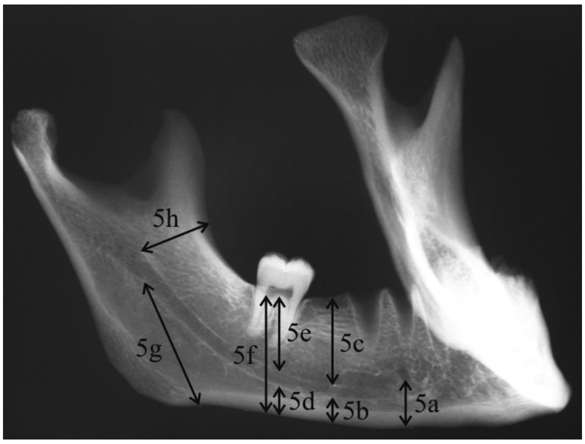

Figure 1. Selected anthropometric parameters describing the topography of the mandibular canal in a radiogram; 5a, 5b, 5c, 5d, 5e, 5f, 5g — abbreviation — see text.

of the Department of Anatomy of the Pomeranian Medical University in Szczecin, acquired during archaeological excavations in the cemetery near the church of St. Joseph in Szczecin in 1969–1970;
— 34 skulls from individuals living in the Middle Ages constituting a part of the collection kept at the Department of Human Biology, the University of Wroclaw, acquired during archaeological excavations carried out in 1959–1989 at the cemetery in Sypniewo (necropolis dated to the 11–13th centuries).

All skulls were from male individuals classified as adultus (age at death 30–35 years) or maturus (50–55 years) and represented European populations.

The age and sex of individuals were determined based on the morphology of the skull [9, 10, 18], the obliteration of cranial sutures [9, 10] and the degree of tooth wear according to the scoring system by Brothwell [9].

The criteria for inclusion in the study were as follows: adult age, male sex, good preservation of the bone material (i.e. standing teeth in the mandible); if the teeth were lost post-mortem and there was no alveolar atrophy related to the loss of dentition, the study also included the mandibles without the third molar erupted if the analysis of the bone material indicated its adult age.

The exclusion criteria were as follows: damage to the bone material preventing all measurements, and developmental anomalies of the mandible.

Radiograms of the analysed mandibles were acquired using X-ray machine Multa 320 type X-18 made by FARUM manufacturer with the following parameters: the focal distance was 100 cm, exposure conditions: voltage 85 kV, current 125 mA, exposure time 0.8 s at the Department of Anatomy Pomeranian Medical University in Szczecin. Relevant measurements were taken on the radiograms using an electronic callipers (with accuracy to the nearest 0.01 mm) three times by one experienced observer. Measurement error was estimated.

To define the topography of the mandibular canal on X-ray images, we took the following anthropometric measurements (Fig. 1), also used by other researchers [8, 30, 43, 45, 50, 51, 52, 57, 61, 63, 67]:
— 5a. Distance between the base of the mandible and the inferior margin of the mental foramen — *Bas.Ma.-For.Me.*;
— 5b. Distance between the base of the mandible and the bottom of the mandibular canal at the level of the first molar — *Bas.Ma-Ca.Ma. I*;
— 5c. Distance between the top of the mandibular canal and the crest of the alveolar arch at the level of the first molar — *Ca.Ma.-Arc.Alv. I*;
— 5d. Distance between the base of the mandible and the bottom of the mandibular canal at the level of the second molar — *Bas.Ma-Ca.Ma. II*;
— 5e. Distance between the top of the mandibular canal and the crest of the alveolar arch at the level of the second molar — *Ca.Ma.-Arc.Alv. II*;
— 5f. The height of the mandibular body measured at the level of the second molar — *He.Ma.Bo.II*;
— 5g. Distance between the base of the mandible near the gonial angle and the inferior margin of the mental foramen (in the projection of the lowest point of the base of the uvula) — *Bas.Ma.-For.Ma.*;
— 5h. Distance between the mandibular foramen and the anterior margin of the mandibular ramus — *For.Ma.-Mar.Ant.*

Statistical analysis

Collected data were analysed with statistical methods using Statistica 7.1 software. The normality of distribution was verified with the Shapiro-Wilk test for two datasets (separately for the measurements taken on the left and right sides of the mandible). Metric features of modern mandibles from the beginning of the 20th century and those dated for the Middle Ages were compared using Student's t-test or its non-parametric equivalent, the Mann-Whitney U test (only in justified cases when the distribution of data was non-normal). Measurements taken on the left

Table 1. Basic statistics of the analysed anthropometric features and results of comparative analyses for the two series of mandibles

Parameter	Modern skulls (n = 92)				Medieval skulls (n = 34)					
	Mean ± SD	Median	Minimum	Maximum	Mean ± SD	Median	Minimum	Maximum	Student's t test	Mann-Whitney U test
Bas.Ma-For.Me. R	12.36 ± 1.85	12.35	8.64	18.05	11.65 ± 1.72	11.71	7.26	14.39	> 0.51	> 0.10
Bas.Ma-For.Me. L	12.05 ± 1.84	12.18	7.61	16.47	11.56 ± 1.67	11.30	7.94	15.08	> 0.17	> 0.15
Bas.Ma-Ca.Ma. I R	7.57 ± 1.52	7.38	3.75	12.33	6.93 ± 1.44	6.93	3.77	9.96	**< 0.04**	> 0.11
Bas.Ma-Ca.Ma. I L	7.44 ± 1.52	7.20	4.06	11.53	7.11 ± 1.58	7.17	3.22	10.85	> 0.38	> 0.54
Ca.Ma.-Arc.Alv. I R	13.98 ± 2.92	14.99	8.91	21.72	16.10 ± 3.97	16.25	4.45	21.98	> 0.08	> 0.06
Ca.Ma.-Arc.Alv. I L	15.19 ± 3.04	15.61	7.87	21.92	16.25 ± 3.63	15.87	6.69	23.58	> 0.10	> 0.09
Bas.Ma-Ca.Ma. II R	7.75 ± 1.83	7.66	2.95	13.90	7.05 ±1.70	7.05	3.90	10.94	**< 0.05**	> 0.10
Bas.Ma-Ca.Ma. II L	7.72 ± 2.15	7.44	3.90	17.83	7.27 ± 1.51	7.04	4.16	11.27	> 0.19	> 0.2
Ca.Ma.-Arc.Alv. II R	13.06 ± 2.58	13.09	6.50	19.52	14.96 ± 3.56	15.51	5.21	21.54	**< 0.008**	**< 0.002**
Ca.Ma.-Arc.Alv. II L	13.53 ± 3.18	13.37	6.41	28.79	15.22 ± 3.74	15.82	4.90	23.13	**< 0.02**	**< 0.006**
He. Ma. Bo.II R	23.86 ± 3.15	23.63	16.35	31.38	24.79 ± 3.73	24.75	15.54	31.01	> 0.16	> 0.10
He. Ma. Bo.II L	23.98 ± 3.27	23.93	16.17	31.98	24.45 ± 4.14	25.98	13.92	32.26	**< 0.04**	**< 0.03**
Bas.Ma-For.Ma. R	34.09 ± 3.47	33.95	24.84	41.04	33.90 ± 3.34	34.41	25.32	39.92	> 0.77	> 0.83
Bas.Ma-For.Ma. L	34.17 ± 3.48	34.01	24.85	42.76	34.56 ± 3.64	34.93	27.38	42.76	> 0.57	> 0.54
For.Ma-B.P. R	12.33 ± 1.95	12.44	7.15	17.00	11.61 ± 2.37	11.72	7.76	17.42	> 0.08	> 0.058
For.Ma-B.P. L	11.97 ± 2.12	12.04	7.39	16.71	11.24 ± 1.62	11.15	7.91	15.08	> 0.07	> 0.06

All measurements in millimetres, SD — standard deviation; L — left; R — right; rest abbreviations — see text

and right sides of the mandible were compared using Student's t-test for paired samples or, in justified cases, its non-parametric counterpart, the Wilcoxon matched-pairs test [54].

The probability of type 1 error (level of statistical significance) was adopted at $p = 0.05$.

RESULTS

The basic statistics of the analysed anthropometric features of mandibles from two series of skulls (modern and medieval) as well as the results of statistical analyses carried out to identify significant differences between the compared features of mandibles are presented in Table 1.

The comparison of modern and medieval skulls for the topography of the mandibular canal revealed significant differences in several parameters (Table 1). The distance between the base of the mandible and the bottom of the mandibular canal at the level of the first and second molars on the right side in modern skulls was longer than in medieval skulls ($p < 0.05$). In medieval skulls, the distance between the top of the mandibular canal and the crest of the alveolar arch was longer on the right and left sides, $p < 0.005$. The height of the mandibular body on the left side was greater in the medieval skulls.

Statistics describing the symmetry in the mandibular anatomy for both analysed samples of skulls are presented in Table 2.

Significant differences were found for two parameters of mandibles from modern skulls: the distance between the top of the mandibular canal and the crest of the alveolar arch at the level of the second molar ($p < 0.05$), and the distance between the mandibular foramen and the margin of the anterior mandibular ramus ($p < 0.007$; Table 2). There were no significant differences between measurements taken on the right and left sides of the medieval skulls.

DISCUSSION

Knowledge of the topography of the mandibular canal and its foramina is necessary for every dentist or dental surgeon dealing with implantology, tooth extractions, surgical repair of mandibular fractures [3, 11, 13, 52, 64], or the transposition of the inferior alveolar nerve [60]. Today, it is difficult to imagine preoperative diagnostic procedures without performing an X-ray study, be it classical radiography or more advanced computed tomography [3, 64, 67]. The reason for this are known differences in the position and topography of the mandibular canal and, in some cases, the presence of accessory canals

Table 2. Comparison of measurements taken on the right and left sides in modern and medieval skulls

	Modern skulls (n = 92)		Medieval skulls (n = 34)	
	Student'	Wilcoxon matched-pairs test	Student'	Wilcoxon matched-pairs test
Bas.Ma-For.Me.	> 0.11	> 0.17	> 0.78	> 0.77
Bas.Ma-Ca.Ma. I	> 0.26	> 0.33	> 0.34	> 0.37
Ca.Ma.-Arc.Alv. I	> 0.43	> 0.21	> 0.79	> 0.62
Bas.Ma-Ca.Ma. II	> 0.90	> 0.62	> 0.43	> 0.31
Ca.Ma.-Arc.Alv. II	**< 0.05**	> 0.14	> 0.61	> 0.58
He. Ma. Bo.II	> 0.60	> 0.75	> 0.13	> 0.11
Bas.Ma-For.Ma.	> 0.78	> 0.58	> 0.08	> 0,07
For.Ma-B.P.	**< 0.007**	**< 0.006**	> 0.16	> 0.13

[41, 61]. Certain ethnic differences in the location of the mandibular canal and mental foramen have also been reported [1, 4, 5, 14, 15, 22, 39], and they are extremely important in anthropometric analyses performed during archaeological research or in forensic medicine [5, 15, 19, 37]. Our study investigating modern and medieval skulls revealed differences in the position of the mental foramen between the level of the first and second molars. The mandibular canal at the level of the second molar was ascending, while the position of the mandibular canal in relation to the base of the mandible was lowest under the alveolar arch of the first molar. These observations are consistent with reports by Kilic et al. [32] and Wychowański et al. [66], although values presented by these researchers were slightly lower. Wical and Swoope [65] reported that in skulls with complete dentition preserved, the mental foramen, which is the exit point of the mandibular canal, is most often located below the apex of the premolars' roots, i.e. in the lower third of the mandibular height. The observed trend is consistent with our findings. This rule was also confirmed in studies by Phillips et al. [45] and Al-Khateeb et al. [1]. Apinhasmit et al. [4] observed that the mental foramen was usually located in the middle of the mandible's height. Measurements of the bone height above the canal to the top of the alveolar arch of the mandible strongly depend on the presence of dentition or the time that elapsed since its loss. This distance depends on the degree of bone atrophy, which does not affect the distance between the base of the mandible and the mandibular canal [11, 13, 44, 52, 65]. Soikkonen et al. [52] and Wical et al. [65] argued that the distance between the base of the mandible and the mandibular canal and the mental foramen is reduced in edentulous mandibles with severe alveolar atrophy. The position of the mandibular foramen on radiograms was measured in relation to the base of the mandible and the margin of the anterior mandibular ramus. Values measured in our study were consistent with those reported by Wychowański et al. [66]. The location of the mandibular foramen does not depend on the alveolar atrophy or potential loss of dentition. In medieval mandibles, the mean values of measurements describing the position of the mental foramen and the topography of the mandibular canal in relation to the base of the mandible were lower than in modern mandibles. It should be noted, however, that significant differences were found only between the features describing the position of the mandibular canal in relation to the base of the mandible on the right side of the analysed mandibles. Thus, the position of the mandibular canal in medieval skulls is lower than in modern skulls. No accessory mandibular canals were observed, which also highlights ethnic homogeneity of analysed bone material. Al.-Siveedi et al. [2] reported a higher incidence of accessory mandibular canals among Malaysians compared to Chinese or Indian populations.

Analysis of face and skull asymmetry is extremely important due to the need for extensive diagnostics in orthodontic treatment [6, 12, 25, 28, 49] in paediatric surgery before the repair of cleft lip and palate [26, 35] and in forensic medicine and anthropology [6, 7, 20, 55]. In maxillofacial surgery, the analysis is performed before the surgical treatment of congenital asymmetrical distortions, such as hemifacial microsomia or plagiocephaly, surgeries of craniofacial tumours, facial clefts, severe craniofacial fractures or treatment of condylar hypoplasia [3, 11, 28, 53]. Our research revealed significant differences in the symmetry of the mandible only in modern skulls. We found differences in the distance between the top of the mandibular canal and the crest of the alveolar arch at the level of the second molar, and the distance between the mandibular foramen and the margin of the anterior mandibular ramus. No statistically significant differences were found in medieval skulls.

CONCLUSIONS

Our study revealed differences in the position of the mandibular canal between modern and medieval skulls, but also findings reported in the literature, which confirms the presence of both geographical and chronological differences between populations.

Knowledge of variability in the position of the mandibular canal between different local populations is fundamental for the correct interpretation of findings from diagnostic radiological studies used in dental practice and for the planning and preparation of effective anaesthesia and implant placement, as well as in forensic odontology or analysis of archaeological bone materials.

Institutional Review Board Statement

The study protocol was approved by the Bioethics Committee, Pomeranian Medical University in Szczecin, Poland, decision no. KB-0012/161/17 of 18 December 2017. The study complies with the Declaration of Helsinki.

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Conflict of interest: None declared

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