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The role of mandibular morphological markers in determining sex and age: anatomical and anthropometric analysis

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Background: *Sex estimation is a very important part of anthropological and forensic research. After the pelvic skeleton, the skull is the easiest place to distinguish sex. The morphological characteristics of the mandible, which is the largest and strongest bone in the skull, play an important role in sex estimation because it varies according to age, sex and race.*

Materials and methods: *In our study, mandibular length (ML), symphysis height (SH), bimental width (BMW), bicondylar width (BCW), bigonial width (BGW), ramus height (RH) and ramus width (RW) were morphologically examined on 130 dry mandibular bones of which age and sex were estimated.*

Results: *Bigonial width, a key indicator of mandibular width, also showed significant differences between the sexes in all age groups (p < 0.05), with males having wider mandibles. Other significant differences were observed for bimental width in the 20–25, 31–35 and 51–55 age groups, and for bicondylar width in the 20–25 and 31–35 age groups. On the other hand, ramus width showed no statistically significant differences between males and females in any age group, suggesting a more uniform characteristic between the sexes.*

Conclusions: *In our study, it can be seen that there are significant sex differences in the various dimensions of the mandible, and that males in general have larger dimensions compared to females. In this context, the morphological findings of our study provide an accurate estimation of the age and sex of the individual.* (Folia Morphol 2026; 85: e01726032)

Keywords: mandible; anatomy; morphology

IINTRODUCTION

The mandible is the strongest bone in the skull and is also important for functions such as chewing and speaking [33]. Mandible morphology varies between individuals according to age, sex and genetic factors. Particularly, features such as the shape of the mandibular ramus, the size of the mental tubercle, and the body height of the mandible are important in sex estimation [9]. Sometimes only the body or the ramus of the mandible is available, in which case regional measurements are important so that the data from the anthropological analysis can be used for a highly accurate estimation of sex [18] The morphological differences between males and females of the same species, known as sexual dimorphism, are pronounced in the human mandible [2]. Many

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studies have been conducted on these dimorphic features to establish techniques for estimating sex [10]. The analysis of mandible features provides a reliable and non-invasive approach to sex determination, thus contributing significantly to the resolution of forensic investigations and the reconstruction of population demography [4].

In general, males have a stronger and larger mandible than females. There are biomechanical differences between male and female mandibles with regard to the pressures applied during biting and chewing [8]. Anthropologists and forensic experts use mandibular length, height and width measurements to differentiate males and females [30]. Shape dimorphism plays an important role in sex differentiation through analysis of mandibular characteristics, along with size dimorphism. Females generally have a mandibular morphology characterized by a rounded and graceful shape, while males tend to have more pronounced and sharp mandibular angles, a larger mental projection and a more robust mandibular body [32].

When the anatomical structure of the lower jaw is examined, there is a disc between the temporal bones and the temporomandibular joint. It is responsible for chewing movements and other functions [7]. The mandible also plays a vital role in dental procedures, particularly in the placement of mandibular implants. For example, the presence of lingual concavity in the posterior mandible is a morphological feature that should be considered when placing implants [11]. However, because the mandible is the largest bone in the face, and because of its location and structural characteristics, it is often the site of fractures as a result of facial trauma [25].

Many factors, including environmental, genetic, nutritional and hormonal regulators, influence sex-related morphological differences [17]. Advanced analytical tools and understanding of sexual dimorphism found in the human mandible enable investigators and forensic experts to effectively determine the biological sex of an individual from skeletal remains. This process facilitates forensic investigations and the reconstruction of past populations [23]. The analyses used in anthropological calculations are generally based on North American or European skeletal collections [13].

This study was conducted extensively on dry mandibles, with age and sex estimated through anthropological assessments, and there are few studies in the literature in this context. Such studies have important applications in fields such as forensic medicine, anthropology and dentistry, and aim to biologically identify individuals.

MATERIALS AND METHODS

In our study, together with an anthropologist, we estimated age using the relevant references. The skeletal specimens used in our study come from the Karlik Tepesi Necropolis in Battalgazi, Malatya, Eastern Anatolia, Turkiye. This site was excavated by the Malatya Museum Directorate in 2020. The necropolis, dated to the 3rd–6th centuries AD based on grave goods, contains a total of 259 individuals recovered from 17 graves (Late Roman–Early Byzantine period). The study was carried out on 130 dry mandibles (71 males, 59 females), whose age and sex were estimated anthropologically according to the literature. The criteria of Bass (1987), Brothwell (1981), Krogman-Iscan (1986) and Olivier (1969) were used for sex estimation of skeletons [5, 6, 19, 24]. In young adults, epiphyseal aging (Brothwell, 1981) and in adults symphysis pubis (Todd, 1920), auricular surface (Lovejoy et al., 1985), proximal sections of clavicle, humerus and femur (Kaur-Jit, 1990) and tooth wear (Brothwell, 1981) were used [3, 6, 16, 21, 31]. Mandibles exhibiting visible pathological changes such as alveolar bone resorption, periodontal lesions, cysts, or other deformative anomalies were excluded from the study to minimize measurement bias.

As the present study was conducted on dry bones from archaeological contexts, ethics committee approval was not required. The measurements were performed according to the 7 parameters defined in Figure 1.

In order to minimize the error rate in the measurements, measurements were taken twice by a single investigator and the averages were calculated. Since all measurements were conducted by a single researcher, intraobserver error was assessed through repeated measurements on a subset of the sample. The calculated %TEM values for each variable confirmed the consistency and precision of the measurements. Specifically, %TEM values ranged from 0.004% (bicondylar breadth) to 1.418% (ramus height), with the following results: mandibular length (0.279%), ramus breadth (0.006%), bigonial

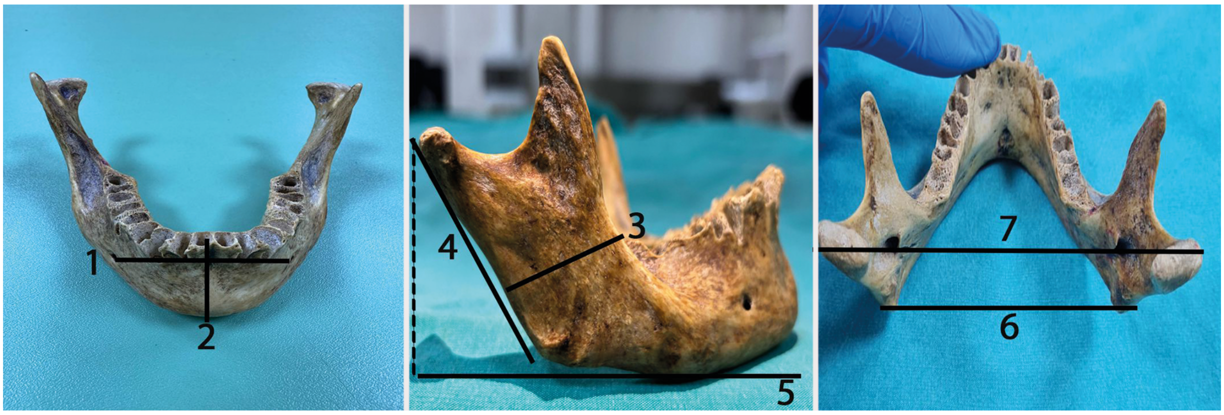

Figure 1. 1 — bimental width; 2 — symphysis height; 3 — ramus width; 4 — ramus height; 5 — mandibular length; 6 — bigonial width; 7 — bicondylar width.

breadth (0.073%), bimental breadth (0.813%), and symphysial height (0.595%). All values remained well below the commonly accepted threshold of 1.5%, indicating a high level of measurement reliability across all variables included in the study. Measurements on dry bones were made manually using a digital caliper (Mitutoyo) with a precision of 0.1 mm. Measurements were made on the dry bones of individuals estimated to be between 20–55 years of age with the help of digital caliper.

Following the literature review [3, 6, 25, 29], the following parameters were measured on the mandible using digital calipers: mandibular length (ML), symphysis height (SH), bimental width (BMW), bicondylar width (BCW), bigonial width (BGW), ramus height (RH), ramus width (RW).

Statistical analysis

Normality of the data was assessed using histograms, Q-Q plots, and the Shapiro–Wilk test. The homogeneity of variance was examined by the Levene's test. In binary comparisons, the independent two-sample *t*-test and Mann–Whitney U test were used for quantitative variables. The data were analyzed with the R 3.2.2 software (www.r-project.org). A p-value < 0.05 was considered statistically significant.

RESULTS

In our study, measurements were made on 130 mandibles (male 71, female 59). The mean ± standard deviation values of the mandibles used in our study are shown in Tables 1–7. Table 1 presents the descriptive statistics of mandibular length (ML) measurements by age group, including the mean, standard deviation, and range.

Mandibular length was generally longer in males than in females. Especially in the age groups 31–35 and 46–50, significantly higher values were measured in males ($p < 0.05$). No significant difference was found in the other age groups. SH measurements showed a significant difference between the sexes only in the 36–40 age group ($p < 0.05$), in this age group SH was higher in males than in females.

Bimental width was significantly higher in males than in females in the 20–25, 31–35 and 51–55 age groups ($p < 0.05$).

Bigonial width: males had significantly wider values than females in all age groups ($p < 0.05$). This parameter exhibited the most pronounced sex-based differences across all age groups.

Bicondylar width was significantly greater in males in the 20–25 and 31–35 age groups ($p < 0.05$). The difference was not statistically significant in the other age groups.

For ramus width measurements, no statistically significant difference was found between the sexes in any age group ($p > 0.05$).

For ramus height measurements, a significantly higher ramus height was found in males than in females in all age groups. This parameter demonstrated the most pronounced sexual dimorphism among those studied.

Table 1. Mandibular length (ML) measurements by age group [mean ± standard deviation (SD), min–max values in mm].

Age	Male		Female		p
	Mean ± SD	Min–max	Mean ± SD	Min–max	
20–25	104.5 ± 8.68	96.50–116.0	92.83 ± 5.57	86.50–97.0	0.086
26–30	103.5 ± 5.36	95.50–108.5	104.0 ± 2.12	102.5–105.5	0.816
31–35	106.0 ± 3.82	101.0–111.5	97.17 ± 1.52	95.50–98.50	0.009*
36–40	105.3 ± 5.30	94.50–111.0	107.0 ± 4.13	102.5–112.0	0.561
41–45	111.4 ± 6.94	105.0–121.0	106.3 ± 5.30	102.5–110.0	0.418
46–50	106.9 ± 5.06	100.5–6.20	100.5 ± 6.20	87.50–106.5	0.04*
51–55	104.7 ± 4.02	99.0–111.0	104.0 ± 3.72	100.0–110.0	0.771

Table 2. Symphysis height (SH) according to age groups mean ± standard deviation (SD), minimum and maximum values [mm].

Age	Male		Female		p
	Mean ± SD	Min–max	Mean ± SD	Min–max	
20–25	34.19 ± 1.87	31.72–37.42	29.64 ± 4.82	24.73–34.37	0.053
26–30	35.55 ± 10.73	26.15–63.03	30.81 ± 3.72	26.22–35.66	0.284
31–35	34.03 ± 3.71	29.90–39.99	31.43 ± 2.77	27.62–34.22	0.198
36–40	33.33 ± 2.00	30.88–35.94	29.24 ± 3.12	26.69–34.71	0.015*
41–45	32.39 ± 6.85	24.05–39.78	29.71 ± 0.71	28.95–30.37	0.537
46–50	32.81 ± 2.43	30.13–35.90	29.90 ± 3.21	25.97–34.95	0.131
51–55	31.96 ± 3.77	28.89–37.25	30.54 ± 4.04	25.33–34.18	0.608

Table 3. Bimental width (BMW) according to age groups mean ± standard deviation (SD), minimum and maximum values [mm].

Age	Male		Female		p
	Mean ± SD	Min–max	Mean ± SD	Min–max	
20–25	45.41 ± 1.47	42.63–46.87	41.61 ± 3.42	38.00–44.81	0.045*
26–30	44.29 ± 2.30	40.70–47.82	44.15 ± 1.58	42.61–46.63	0.899
31–35	45.31 ± 1.93	42.67–48.66	41.60 ± 3.52	35.79–44.81	0.008*
36–40	45.22 ± 2.27	43.21–48.66	44.03 ± 1.75	42.17–46.64	0.312
41–45	45.87 ± 2.83	41.25–50.09	47.16 ± 1.86	45.11–48.85	0.442
46–50	45.74 ± 2.59	42.13–50.94	44.80 ± 2.52	38.85–49.98	0.365
51–55	45.77 ± 2.95	40.88–50.32	42.79 ± 1.65	41.10–45.03	0.037*

Table 4. Bigonial width (BGW) according to age groups mean ± standard deviation (SD), minimum and maximum values [mm].

Age	Male		Female		p
	Mean ± SD	Min–max	Mean ± SD	Min–max	
20–25	100.1 ± 3.97	96.11–104.1	86.62 ± 5.28	80.86–91.23	0.024*
26–30	100.6 ± 7.57	91.24–111.1	87.88 ± 4.32	84.85–92.84	0.024*
31–35	103.0 ± 6.09	97.42–112.9	85.27 ± 3.93	80.74–87.80	0.004*
36–40	103.7 ± 3.69	99.42–108.9	92.00 ± 5.45	86.67–99.14	0.003*
41–45	106.1 ± 2.42	103.4–109.0	92.07 ± 2.72	90.14–93.99	0.002*
46–50	101.7 ± 6.46	93.35–112.8	91.58 ± 4.93	79.94–98.28	0.001*
51–55	103.7 ± 3.90	98.91–107.0	88.05 ± 6.96	78.29–98.34	0.0007*

Table 5. Bicondylar width (BCW) according to age groups mean ± standard deviation (SD), minimum and maximum values [mm].

Age	Male		Female		p
	Mean ± SD	Min–max	Mean ± SD	Min–max	
20–25	120.4 ± 5.39	112.7–125.2	105.7 ± 8.05	100.1–115.0	0.03*
26–30	121.0 ± 8.03	109.6–131.8	106.2 ± 4.70	102.9–109.5	0.05
31–35	118.6 ± 2.46	114.9–121.0	110.2 ± 1.29	109.5–111.7	0.001*
36–40	121.7 ± 7.34	112.3–132.6	113.8 ± 6.07	107.2–119.3	0.167
41–45	116.9 ± 6.90	111.3–127.0	115.4 ± 0.36	115.2–115.7	0.788
46–50	106.0 ± 17.91	85.83–120.1	116.2 ± 3.14	111.6–121.2	0.189
51–55	117.6 ± 4.64	113.0–121.9	112.5 ± 5.03	105.1–116.8	0.132

Table 6. Ramus width (RW) according to age groups mean ± standard deviation (SD), minimum and maximum values [mm].

Age	Male		Female		p
	Mean ± SD	Min–Max	Mean ± SD	Min–Max	
20–25	31.15 ± 2.69	26.60–35.11	28.96 ± 2.35	27.41–32.44	0.182
26–30	29.10 ± 2.09	25.88–32.32	32.06 ± 3.57	27.00–34.63	0.095
31–35	32.04 ± 3.81	23.28–35.32	27.91 ± 3.41	23.74–31.86	0.090
36–40	31.16 ± 1.87	28.74–34.29	31.39 ± 3.21	28.01–37.34	0.886
41–45	28.73 ± 0.89	27.87–29.67	29.51 ± 1.21	28.13–30.38	0.365
46–50	29.46 ± 3.18	25.54–35.38	30.22 ± 2.90	24.56–35.23	0.552
51–55	30.42 ± 1.68	27.92–32.57	29.42 ± 2.24	26.32–32.92	0.324

Table 7. Ramus height (RH) according to age groups mean ± standard deviation (SD), minimum and maximum values [mm].

Age	Male		Female		p
	Mean ± SD	Min–max	Mean ± SD	Min–max	
20–25	57.88 ± 6.00	50.09–67.64	47.67 ± 9.78	39.42–61.81	0.038*
26–30	59.81 ± 6.65	49.90–67.26	46.91 ± 5.37	41.10–51.70	0.015*
31–35	62.23 ± 3.24	55.56–64.80	48.78 ± 5.77	44.16–57.15	0.0002*
36–40	61.96 ± 2.33	58.22–63.81	50.03 ± 7.32	38.26–56.60	0.001*
41–45	62.58 ± 7.57	56.04–72.98	47.53 ± 3.21	45.25–49.80	0.061
46–50	57.04 ± 2.08	47.62–64.60	47.58 ± 4.30	40.00–56.25	0.0005*
51–55	60.82 ± 7.59	52.89–73.71	49.74 ± 8.14	32.81–58.15	0.013*

DISCUSSION

The mandible, the strongest bone in the human body, provides rich information about the biological profile and sex of individuals [14]. In our study, measurements were made on the dry bones of individuals estimated to be between 20–55 years of age with the help of digital calipers. Studies have shown that morphological differences of the mandible can be observed between the sexes. The morphological features of the anterior body of the mandible and the shape of the symphysis region can be used to predict sex differentiation with high accuracy in the study by Singh et al. [28]. In our study, SH was statistically different between sexes only in the 36–40 age range ($p < 0.05$). There was no difference between sexes in other age groups. Symphysis height is generally associated with areas of robustness and muscle attachment, which are more prominent in men. Karmali et al. stated that the morphology of the mandible is affected by factors such as sex, race and dietary habits and that these features should be taken into consideration when performing morphological analyses of the mandible [15]. Age-related changes in the mandible are critical points to be considered. As individuals age, the morphology of the mandible may undergo significant changes as affected by factors such as dental health and bone density [20]. In our study, ML was generally longer in men, particularly in the 31–35 and 46–50 age groups. Especially in the 31-35 and 46-50 age groups, higher ML was measured in men ($p < 0.05$). No significant difference was found in other age groups. This difference is consistent with patterns of sex dimorphism in which males generally exhibit larger skeletal structures than females. Öztürk et al. [26] found that teeth play an important role in determining mandibular morphology and that teeth cause changes in the shape and structure of the mandible. This study is consistent with the study by Hutchinson et al. who reported that tooth loss can adversely affect masticatory performance and subsequently change the morphology of the mandible [12]. A thorough understanding of these changes is essential for the identification of anatomical variations and is of significant clinical importance in the context of surgical planning. Sukegawa et al. [29] investigated how the presence and absence of third molars may affect the occurrence and pattern of mandibular fractures, especially in elderly populations. The methodology used in the measurement of morphological parameters is extremely important. To ensure the reliability of the collected data, measurements using calipers are essential. Ahn et al. [1] used structural equation modelling to analyze the correlation between cross-sectional morphology and three-dimensional facial skeletal patterns and emphasized the need for precise measurement techniques in morphological studies. Pfaff et al. [27] tried to increase the accuracy of anatomical evaluations by morphometric analysis of the mandible using advanced image techniques. Bicondylar width and ramus height are critical indicators of the overall size and robustness of the mandible, which may vary in different age groups and sexes. Bicondylar width, the distance between the mandibular condyles, was higher in males (45.28 mm) compared to females (44.20 mm) with a p-value of 0.013. Although the difference in averages is not large, it is still noticeable and is associated with larger mandibular condyles, especially in men, which help to stabilize the masticatory muscles. Narwani and Vijaylaxmi [22] supported this idea in their study, investigating variations in ramus width in different populations.

Forensic anthropologists emphasize the importance of morphological measurements of the mandible to help in the completion of unknown remains, as the mandible can provide critical information about the age, sex and ancestry of the individual. In addition, knowing the morphological variations of the mandible in dental practice guides the planning of implant treatment and leads to successful results.

CONCLUSIONS

As a result, the study of age- and sex-related mandibular morphology spans a variety of disciplines from anatomy to anthropology. The findings of our study highlight significant sexual dimorphism in several mandibular measurements, with males consistently exhibiting larger and more robust mandibles than females. Mandibular length, symphysis height, bicondylar width, bigonial width, ramus width and ramus height all showed statistically significant differences between the sexes. The absence of a significant difference in ramus width may suggest that certain aspects of mandibular morphology, particularly those related to muscle attachment and function, are less affected by sex. Integration of morphometric measurements, consideration of demographic factors, and application of improved methodologies are crucial to advancing our understanding of mandibular anatomy. As research continues to evolve, it is imperative to maintain a rigorous approach to data collection and analysis to ensure that findings are robust and applicable to real-world scenarios.

ARTICLE INFORMATION AND DECLARATIONS

Data availability statement

Data will be made available upon reasonable request.

Ethics statement

This study was performed on dry bones, ethics committee approval was not required.

Author contributions

Adem Tokpınar and Yarenkür Alkan designed the study and performed the bone measurements. Adem Tokpınar wrote, reviewed and edited the manuscript. Yarenkür Alkan performed the statistical analysis. All authors read and accepted the published version of the manuscript.

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Conflict of interest

The authors declare that they have no competing interests.

Supplementary material

None.

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