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Anthropometric evaluation of mandibular characteristics in the medieval Kurdish population of Girê Kortikê: Sex-based variations and comparative analysis

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ABSTRACT

Introduction: This research seeks to develop population-specific standards for skeletal sex determination, focusing on the medieval Kurdish population of Girê Kortikê and the mandible, a skull component presenting the highest degree of sexual dimorphism. This is the first study of its kind for this population. The research's primary objectives were to conduct anthropometric evaluations of several mandibular characteristics within this population, assess sex-based variations, determine relationships between various mandibular sizes, and contrast these findings with other existing studies.
Materials and methods: A total of 121 mandibles (55 women, 66 men) were measured using 14 distinct anthropometric techniques, applying Pearson correlation coefficients, student's t-test, and principal component analysis (PCA) for comparison.
Results: The study examined and discussed disparities between some chosen mandibular measurements and data from other populations. Statistically significant sex differences ($p < 0.05$) and correlations were identified in 12 of the anthropological measurements. The research found that the greater the height of the symphysis (GNI), the higher the foramen mentale height (FBB). Average measurements significantly deviated from the medieval Kurdish population when compared to populations in Santa Maria Xigui, Mexico (XIG), and Mexico City (MEX).
Conclusion: No correlation was found between the height of the mandibular body (HML) and the mandible length (MLT). The study suggested distinct mandibular angle (MAN) sizes between sexes, indicating unique characteristics within the Girê Kortikê population, warranting further research for a more comprehensive evaluation. In conclusion, these findings emphasize the mandible's anatomical, historical, and cultural relevance in sex determination within the Girê Kortikê population.

1. Introduction

Throughout an individual's life, the human mandible experiences extensive modifications in terms of size and shape [1]. There are even instances where certain morphological alterations of the mandible among individuals end up being unique or associated with factors such as ethnicity, sex, and age. It's crucial to realize that during the stages of mandibular development, growth rates fluctuate based on sex [2].

The intricate anatomy of this bone (comprising a body with two confined surfaces and two borders, where the rami start on both sides at the mandibular angle, containing lower teeth, assisting in chewing, forming the lower jawline, and connecting with the temporal bone via the temporomandibular joints) allows for its use in human identification and profile reconstruction. Gamba et al. [3] asserted that identity could be defined as a set of personal characteristics distinguishing one person from another. This identification process is also pivotal in the artistic reconstruction of facial structures from an unidentified skull [4].

Variations in skull anatomy are numerous, and identifying these differences continues to be a research area in various populations around the globe. Notably, measurements of bones can be influenced by

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shifts in dietary or environmental conditions, secular trends, and different population groups. Capella et al. [5] postulate that current findings and existing data suggest that sexual dimorphism is pervasive across ethnically disparate populations and metric standards, with most dimorphic measurements varying due to environmental and genetic influences.

Over recent decades, state-of-the-art techniques and diverse technological advancements have furnished remarkable strategies that probe into the relationships, life, and activities of past humans. From the point of mandibular development, the impact of muscle attachments on bone size and shape has been evident [6]. Utilizing anatomical knowledge of bones and teeth in conjunction with metric analyses in anthropological studies can facilitate sex estimation – a vital initial step in accurate human identification via cost-effective methods with high precision [7]. The advent of new computerized, virtual, or medical scanning methods, providing increased accuracy and reproducibility, extend traditional osteological resources beyond mere anatomical truth. Excavated biological materials have gained immense popularity in medical, anthropological, and forensic studies, as well as diverse dentistry fields. The data analysis and interpretations provided by scientists have advanced numerous solutions to an array of medical issues. Today, it is feasible to perform examinations and acquire facial, dental, and soft tissue identification results such as anatomical and biological profiles based on cranial conditions. A multi-disciplinary approach and research on mandibular bone can deliver critical insights on a multitude of topics. Issues like comparing how populations have diverged over time can provide invaluable medical and historical data. Well-preserved skeletal parts, including the mandible, can be attributed high diagnostic value, enabling us to study human evolution and the environment's impact on humans.

In the skeleton, craniofacial morphology is one of the best indicators of ethnical phenotype. Differences in facial bone sizes and shapes can reflect disparities in skull proportions. Nevertheless, there should be well-established population-specific variants, and sex-linked differences can vary between groups. Álvarez Villanueva et al. [8] stated that determining sex was a primary element in establishing a subject's biological profile. Bertsatos et al. [9] evidenced that sex-related morphological traits exhibit variability both between and within populations due to multiple factors including genetics, nutrition, secular changes, growth, disease prevalence, and the environment. Various morphological and morphometric characteristics of the mandible linked to muscles and hormonal differences are described in the literature [10].

Suzuki et al. [11] suggested that sex identification could be achieved using principal component analysis (PC), where sex could be determined by homologous modeling of the mandible and the aforementioned analysis. It is important to underline that identification should always be based on multiple techniques, adhering to the anthropological principle of using as many available resources as possible. These measurements should be carried out, evaluated, and validated for each population sample.

Previously, no research has been conducted on the medieval Kurdish population from the Girê Kortikê. The aims of the present study were twofold: firstly, to carry out anthropometric measurements of various mandibular parameters in the Girê Kortikê/medieval Kurdish community and evaluate the sex differences and correlation between mandibular dimensions, and secondly, to identify the most significant mandibular differences between sexes and compare these results with those from other existing studies.

2. Materials and methods

2.1. Sample selection

Diyarbakir, currently the most populous Kurdish city in southeastern Turkey, has historically been a significant habitation site in the region. The Körtiktepe Tumulus (Girê Kortikê) mound, situated in the village of Ağil (Encolîn) en route to Batman and approximately 30 km from Bismil, has become a focal point of scientific research. The imminent threat of flooding due to various dam constructions has increased the urgency of excavations at sites like Körtik Tepe in the Upper Tigris Valley. The rich archaeological heritage and cultural resources unearthed in the area suggest a more ancient and affluent history than previously estimated. Körtik Tepe, in particular, provides unique insights into historical cultural progress, including adaptive strategies to essential needs, habitation and burial practices, tool manufacturing, the evolution of religious beliefs, and related iconography. In the early Middle Ages, references to Kurds began appearing in Arabic sources, not as a specific people, but as a conglomeration of nomadic western Iranian tribes distinct from the Persians. By the High Middle Ages, however, the Kurdish ethnic identity began to crystallize, with explicit evidence of this identity and community cohesion found in 12th and 13th-century texts. The medieval human skeletons used in this study were retrieved from the Körtiktepe Tumulus in the Bismil District of Diyarbakir province during archaeological digs conducted between 2006 and 2007. The skeletons unearthed from the side were inhumed outside of the dwellings and under the floors. The skeletons were buried in a flexed position ("hocker") or semi-hocker position, and some of them were covered with plaster as well. Numerous plastered skeletons also bear traces of ochre on skulls and bones. Most of the skeletons were buried with different grave goods, which may indicate social differentiation between the skeletons. These remains were then forwarded to the Faculty of Medicine at Dicle University for further analysis. Mandibular data for these samples were examined in August 2022.

Standard anthropological techniques were employed to determine age and sex, as well as to perform a morphological examination of the mandibles. Only well-preserved, intact mandibles were included in the sample. Any mandibles exhibiting fractures, fragmentation, deformations, or pathological conditions were omitted from the study. Certain morphological features were used to classify the mandibles by sex; those with pronounced bony landmarks and outwardly curved (everted) mandibular angles were designated as male, while those with comparatively smooth, less discernible features and inwardly curved (inverted) or straight mandibular angles were classified as female.

In total, 121 mandibles (55 women and 66 men) were included in the analysis. The information about precise age at death was not detected for the whole sample, because there wasn't available the Carbon 14 (14C) at the Laboratory. Despite that, all cases were assessed, like mature and adults.

2.2. Landmarks and measurements

In this research, each mandible underwent 14 distinct anthropometric assessments (Table 1, Fig. 1, Fig. 2).

Using a digital electronic caliper (Scala) and a chin caliper (PaleoTech concept), measurements were taken with a precision of 0.1 mm. Prior to the study, the team received training to ensure precise anthropometric measurements of the mandible and accurate interpretation of anatomical details.

2.3. Statistics

After all the measurements had been taken, and the data were statistically analyzed. Statistical analysis was performed with IBM SPSS Statistics for Windows software (Version 28.0. Armonk, NY: IBM Corp.). Pearson's correlation coefficients among continuous variables were calculated. Related to sex, the differences between the groups were analyzed using the student's t-test. The significance level was $p < 0.05$. Principal component analysis (PCA) was used for representative values defined as 'principal components' to highlight any intergroup correlations.

Table 1
Specifics of the mandibular measurements (adapted from Álvarez Villanueva et al. [8]).

Number	Measurement	Abbreviation	Definition
1	Height of symphysis	GNI	The straight line distance from infradentale (ID: the middle point at the top of the septum between the mandibular central incisors) to gnathion (GN: the lowest midline point on the mandible); can be estimated in slightly eroded samples at the lateral incisors; if the alveolus is significantly reabsorbed, the specimen should not be measured.
2	The breadth of the mandibular body	TML	The greatest breadth is gauged in the area of the mental foramen perpendicular to the long axis of the mandibular body.
3	Height of mandibular body	HML	The direct distance from the alveolar process to the lower edge of the mandible, perpendicular to the base at the level of the mental foramen.
4	Foramen mentale height	FBB	The distance between the lower margin of the mental foramen and the basal border of the mandible.
5	Foramen mentale distance to chin	MFA	The distance between the mental foramen and the mental tubercle.
6	Bigonial breadth	GOG	The direct distance between the right and left gonions (GO: the point along the rounded posterior corner of the mandible between the ramus and the body). To identify the point, envision an extended line from the posterior ramus border and the lower body border to form an obtuse angle. The line bisecting this angle meets the curved mandibular border at the gonion.
7	Bicondylar breadth	CDL	The distance between the two most lateral points on the two condyles.
8	Maximum ramus breadth	MRL	The distance between the front point of the mandibular branch and the line connecting the back point of the condyle and the mandible's angle.
9	Minimum ramus breadth	WRK	The smallest width of the mandibular branch measured perpendicular to the height of the ramus.
10	Maximum ramus height	XRL	The distance from the topmost point on the mandibular condyle to the gonion.
11	Mandibular length	MLT	The distance from the chin's front margin, from a central point in a straight line along the posterior border of the two mandibular angles. Position the posterior border of the mandibular branch and the fixed plate with the foremost point of the mental tubercle on the movable back part of the jaw calipers. The mandible can be stabilized by applying pressure with one or two fingers to the left second molar.
12	Length of the body	GGN	Distance from gonion to gnathion.
13	Mandibular angle	MAN	This angle is formed by the body's lower border and the rami's posterior border.
14	Mental angle	GMG	This angle is defined by the lines connecting the mental tubercle with the right and left gonions.

Fig. 1. Example of one mandibular specimen.

2.4. *Comparison*

A comprehensive comparison was conducted on all mandibles to identify variations within the population of the medieval Kurdish community of Girê Kortikê. Moreover, the average values of the current mandibular angle variables (MAN) were compared with data from other diverse populations. These included communities from Santa Maria Xigui, Alfajayucan, Hidalgo, Mexico (XIG), Mexico City (Colección-UNAM) (MEX), non-Han Chinese, India, and adult Italians. These populations were selected and chosen especially because of the information about the same or similar amount of mandibular measurements in them. This was in line with our results, and studies by obtained authors allowed us to find the data for comparison and differentiation.

3. Results

3.1. *Descriptive statistics*

In this research, Table 2 presents the information regarding the mandibular measurements.

3.2. *Statistical differences and correlations*

The variables showed statistically significant differences between males and females for GNI, TML, FBB, MFA, GOG, CDL, MRL, WRK, XRL, GGN, MAN, and GMG. For males, the biggest statistically significant dimensions were for GNI, FBB, MFA, GOG, CDL, MRL, WRK, XRL, GGN, MAN, and GMG, but for females only for TML. The HML and MLT values did not show statistically significant differences between the sexes.

Different correlations were found among male and female mandibles between the measurement values (data not shown in Tables). In male mandibles, statistically significant correlations were between HML and MRL ($r = -0.257$; $p = 0.038$), FBB and MRL ($r = -0.303$; $p = 0.013$), MFA and CDL ($r = -0.281$; $p = 0.022$), TML and WRK ($r = -0.252$; $p = 0.041$), and between MRL and MLT ($r = -0.282$; $p = 0.022$). Only a few mandibular values showed statistically significant correlations for females. GNI and TML, and XRL and GMG ($r = 0.279$; $p = 0.03$ and $r = -0.310$; $p = 0.02$, respectively).

In all mandibles, it was found that the higher the GNI, the greater the FBB ($r = 0.216$; $p = 0.01$). The analysis also showed that there were negative correlations between the GNI and WRK ($r = -0.208$; $p = 0.02$), and MAN ($r = -0.241$; $p = 0.241$). There were negative significant correlations between FBB and TML ($r = -0.223$; $p = 0.14$), MFA ($r = -0.184$; $p = 0.44$), MRL ($r = -0.180$; $p = 0.48$), XRL ($r = -0.219$; $p = 0.016$), GGN ($r = -0.343$; $p = 0.000$), and MAN ($r = -0.319$; $p = 0.000$). MFA was negatively correlated with MRL ($r = -0.270$; $p = 0.003$) and XRL ($r = -0.247$; $p = 0.006$). A negative correlation was also found between GOG and GGN ($r = -0.226$; $p = 0.013$). The higher the MRL, the lower the values of XRL ($r = -0.178$; $p = 0.050$) and MAN ($r = -0.214$; $p = 0.019$).

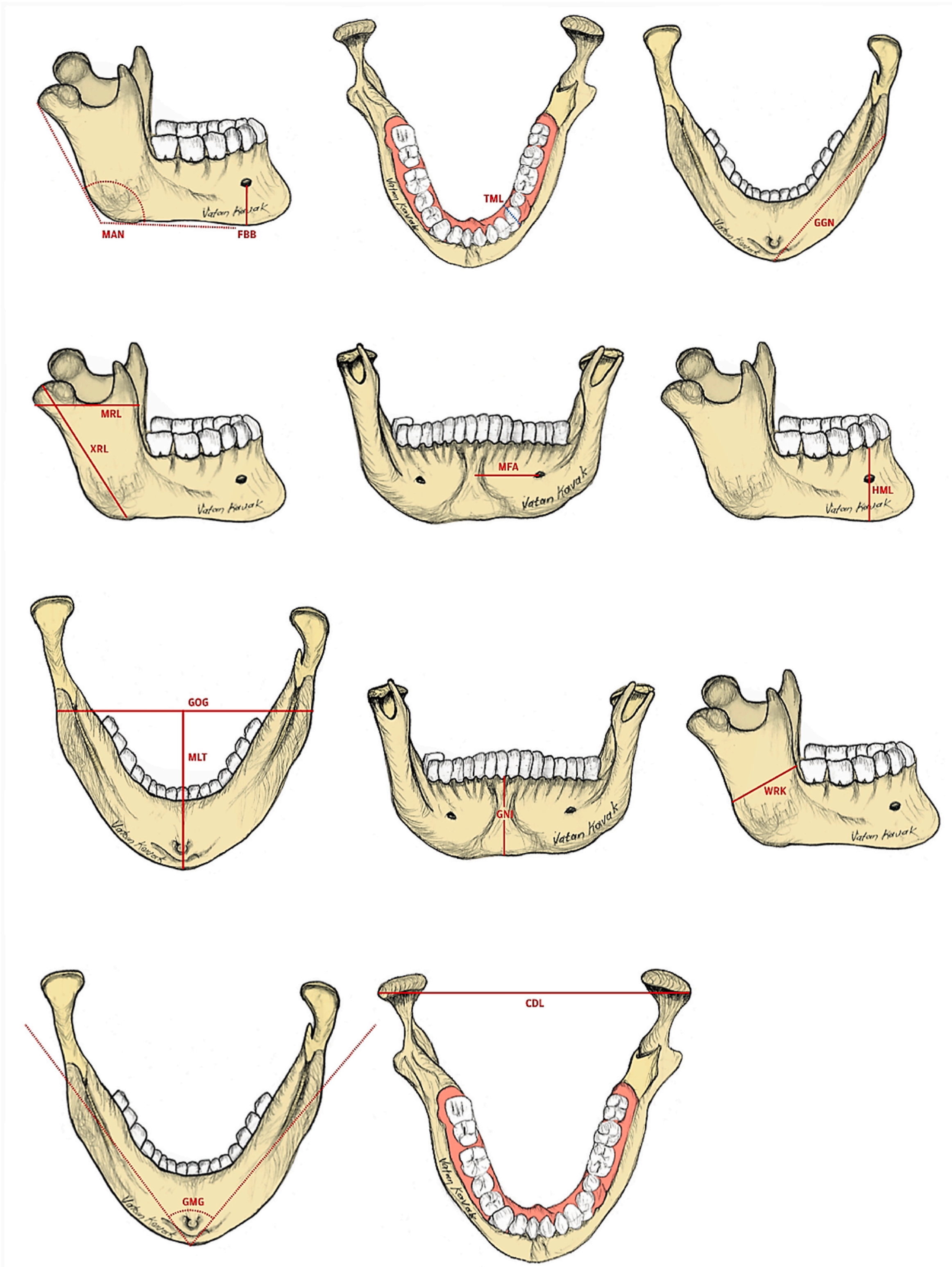

Fig. 2. Mandibular measurements.

3.3. Comparative data

The Kurdish mandible from Girê Kortikê was defined based on its unique dimensions and the average values of the anthropometric measures. Correlations were made between the MAN variables from this study and the average MAN values found in Santa Maria Xigui, Alfajayucan, Hidalgo, Mexico (XIG) and the populations of Mexico City (Colección-UNAM) (MEX) [8], as presented in Table 3. It was further observed that the mean MAN values for males and females displayed significant statistical differences in the medieval Kurdish population.

Table 2
Descriptive statistical findings for mandibular measurements, t-values and p-values of men and women of the Girê Kortikê/medieval Kurdish community.

Number	Value	Male (n = 66)			Female (n = 55)			t-value	Significance
		Mean	SD	Std. Error Mean	Mean	SD	Std. Error Mean		
1	**GNI**	30.05	0.40	0.04	20.75	0.78	0.10	- 2.61	p < 0.05
2	**TML**	10.08	0.20	0.02	10.15	0.15	0.02	- 2.06	p < 0.05
3	**HML**	20.88	0.54	0.06	20.77	0.70	0.09	- 0.95	not significant
4	**FBB**	10.44	0.14	0.01	10.22	0.26	0.03	- 5.48	p < 0.05
5	**MFA**	20.93	0.35	0.04	20.63	0.36	0.04	- 4.49	p < 0.05
6	**GOG**	90.97	0.46	0.05	90.42	1.63	0.22	- 2.39	p < 0.05
7	**CDL**	110.67	1.08	0.13	110.39	0.57	0.07	- 4.09	p < 0.05
8	**MRL**	40.47	0.37	0.04	40.08	0.41	0.05	- 5.47	p < 0.05
9	**WRK**	30.38	0.30	0.03	30.12	0.39	0.05	- 4.92	p < 0.05
10	**XRL**	70.16	1.14	0.14	60.29	1.60	0.21	- 3.36	p < 0.05
11	**MLT**	70.90	0.86	0.10	70.76	1.81	0.24	- 0.51	not significant
12	**GGN**	90.72	0.57	0.07	80.61	1.29	0.17	- 5.89	p < 0.05
13	**MAN**	134.08	5.01	0.61	123.73	5.04	0.68	- 11.25	p < 0.05
14	**GMG**	141.35	4.40	0.54	139.12	6.89	0.92	- 2.07	p < 0.05

*p < 0.05, significant.
Abbreviations: height of symphysis (GNI); breadth of the mandibular body (TML); the height of the mandibular body (HML); foramen height (FBB); foramen-chin distance (MFA); bigonial breadth (GOG); bicondylar breadth (CDL); maximum ramus breadth (MRL); minimum ramus breadth (WRK); maximum ramus height (XRL); mandibular length (MLT); length of the body (GGN); mandibular angle (MAN); mental angle (GMG).

3.4. *Synopsis of the informational value within data*

In this study, the mandibles underwent a PC analysis, which involved processing a comprehensive dataset comprising numerous variables per observation. The analysis aimed to condense the data into a more concise set of summary indices, as depicted in Table 4.

Each principal component represented a mixture of the original variables. The PC parameters were set to 6. The eigen analysis showed that all six principal components have eigenvalues greater than one. These six main components (PC1 – PC6) represented 60.26%.

4. Discussion

Our research provides compelling evidence that the mandibular angle (MAN) measurements present significant differences between sexes, an aspect that enhances the potential for sex identification. This finding resonates with existing studies that have highlighted the critical role of mandibular parameters in sexual dimorphism. Our outcomes align with those from other research that focus on adult sex determination in the Turkish population [12].

The scientific community has been active in exploring similar research trajectories, with numerous studies having employed different imaging techniques to examine dried adult mandibles. Techniques such as panoramic radiography, cone beam computed tomography (CBCT), or standard computed tomography (CT) have been harnessed [13–17]. These imaging tools, which have gained popularity in recent years, allow for an accurate three-dimensional (3D) reconstruction of maxillofacial structures.

Several methodologies have been devised to estimate mandibular differences across populations and sexes, each presenting unique advantages and disadvantages. Anthropometric mandible measurements

Table 4
The results of the principal component analysis (PCA).

Principal Component (PC)	Eigen value	Contribution rate (%)	Cumulative contribution rate (%)
1	2.43	17.38	17.38
2	1.28	9.19	26.58
3	1.24	8.90	35.49
4	1.19	8.52	44.01
5	1.16	8.35	52.36
6	1.10	7.92	60.29

Table 3
Comparative data for mandibular measurements (mm) of the Girê Kortikê/medieval Kurdish community, Santa María Xigui, Alfajayucan, Hidalgo, México (XIG) and Mexico City (Colección-UNAM) (MEX) populations.

Number	Value	Girê Kortikê/medieval Kurdish		Santa María Xigui, Alfajayucan, Hidalgo, México (XIG)		Mexico City (Colección-UNAM) (MEX)	
		Male (n = 66)	Female (n = 55)	Male (n = 30)	Female (n = 26)	Male (n = 75)	Female (n = 33)
		Mean ± SD	Mean ± SD	Mean ± SD	Mean ± SD	Mean ± SD	Mean ± SD
1	**GNI**	30.05 ± 0.40	20.75 ± 0.78	36.54 ± 2.81	32.70 ± 2.55	31.97 ± 3.89	29.97 ± 4.76
2	**TML**	10.08 ± 0.20	10.15 ± 0.15	12.36 ± 1.88	11.67 ± 1.16	11.13 ± 1.33	10.94 ± 1.28
3	**HML**	20.88 ± 0.54	20.77 ± 0.70	32.74 ± 2.25	29.17 ± 2.29	29.43 ± 3.53	28.42 ± 3.31
4	**FBB**	10.44 ± 0.14	10.22 ± 0.26	15.92 ± 1.64	14.47 ± 1.27	14.41 ± 1.32	13.79 ± 1.57
5	**MFA**	20.93 ± 0.35	20.63 ± 0.36	28.41 ± 2.05	26.60 ± 1.28	27.57 ± 2.04	27.03 ± 1.85
6	**GOG**	90.97 ± 0.46	90.42 ± 1.63	92.22 ± 5.16	86.71 ± 4.56	90.06 ± 5.41	84.80 ± 4.22
7	**CDL**	110.67 ± 1.08	110.39 ± 0.57	123.96 ± 4.03	119.41 ± 3.62	116.85 ± 5.81	111.33 ± 6.11
8	**MRL**	40.47 ± 0.37	40.08 ± 0.41	45.06 ± 3.26	44.05 ± 3.49	43.44 ± 3.06	41.46 ± 2.93
9	**WRK**	30.38 ± 0.30	30.12 ± 0.39	34.36 ± 2.38	32.95 ± 3.31	32.19 ± 2.57	30.87 ± 2.38
10	**XRL**	70.16 ± 1.14	60.29 ± 1.60	69.13 ± 3.45	63.30 ± 5.19	68.91 ± 4.98	64.08 ± 4.68
11	**MLT**	70.90 ± 0.86	70.76 ± 1.81	80.03 ± 4.20	76.00 ± 3.48	79.87 ± 4.23	78.27 ± 4.58
12	**GGN**	90.72 ± 0.57	80.61 ± 1.29	75.90 ± 4.17	71.65 ± 3.63	76.07 ± 4.35	72.97 ± 4.79
13	**MAN**	134.08 ± 5.01	123.73 ± 5.04	121.67 ± 6.78	123.58 ± 5.82	123.28 ± 6.98	124.82 ± 7.07
14	**GMG**	141.35 ± 4.40	139.12 ± 6.89	75.50 ± 4.89	74.69 ± 4.15	73.04 ± 4.94	71.06 ± 4.42

Abbreviations: height of symphysis (GNI); breadth of the mandibular body (TML); the height of the mandibular body (HML); foramen height (FBB); foramen-chin distance (MFA); bigonial breadth (GOG); bicondylar breadth (CDL); maximum ramus breadth (MRL); minimum ramus breadth (WRK); maximum ramus height (XRL); mandibular length (MLT); length of the body (GGN); mandibular angle (MAN); mental angle (GMG).

benefit from tools such as sliding calipers. However, selecting the appropriate methodology can become challenging when access is limited to specific parts or fragmented remains.

Cephalometric techniques have been extensively employed in research. For instance, Vallabh et al. [18] have utilized image datasets and cadaver samples to investigate mandible morphometrics and sexual dimorphisms. Patil et al. [19] underlined the ease of radiographing the mandible to identify specific linear measurements of mandibular branches.

In other studies, the mandibular branch has been demonstrated as a reliable tool for sex determination due to its resistance to degradation processes [20,21]. Astuti et al. [22] concluded that the accuracy of sex determination depends largely on the available skeletal parts and the number of bone fragments.

Analyzing teeth has been a common approach to evaluate mandibular morphometry [23]. However, several factors can influence the outcomes, including tooth loss, malocclusions, and chewing patterns [24]. By exploring the correlation between maxillary and mandibular dental arch dimensions, researchers can gain insights into the complex interactions between various genetic and environmental factors [25].

Research by Chole et al. [26] discovered that sex significantly influenced the gonial angle and antegonial region, but these factors were not affected by age or dental status. Their findings suggested that these variations could serve as tools for sex determination, but not for age determination. These are important observations as most features in the skull and mandible are age-dependent, which poses challenges for sex differentiation based solely on dental characteristics [27].

A variety of studies have underscored the importance of bones, including the mandible, in providing reliable into growth and changes over time. Researchers have posited that the mandibular ramus, which can resist damage and decay, could prove a valuable tool for sex determination. Koju et al. [28] found that the mandibular ramus and condyle were the most sexually dimorphic due to consistent morphological modifications and remodeling during growth.

Further studies have pointed out that mandibular length is strongly associated with chronological age [29]. This positive correlation between age and ramus length could be exploited to accurately predict if an individual is at least 18 years old. Gillet et al. [30] suggested that the mandible was more accurate for individuals aged over 40 years compared to those below that age. The heterogeneity of skeletal traits across geographic areas and populations is noteworthy [31].

Modern human mandible measurements embody the impact of a multitude of factors on its shape and size. The findings from Girê Kortikê/medieval Kurdish population are aligned with prior research, indicating a decline in ortofunctionality due to advanced age and food processing methods. Bergman et al. [32] pointed out that historical mandible studies provide a fresh angle on morphological diversity.

We compared the findings of our research with data from a study in Mexico City (Colección-UNAM) (MEX) and another from Santa Maria Xigui, Alfajayucan, Hidalgo, Mexico (XIG) [8]. The first MEX sample contained 108 mandibles (33 female and 75 male) from individuals who died between 1990 and 2010. The mean age for males was 55.1, ranging from 20 to 100 years, whereas for females, it was 50.7, with ages ranging from 20 to 88 years. The second XIG sample consisted of 56 mandibles (26 female and 30 male) from individuals who passed away between 1960 and 2010. The mean age for males was 49.2, with ages spanning 27–63 years, while for females, it was 61.7, with ages ranging from 44 to 82 years. Differences between sexes were noted in minimum ramus breadth (WRK) and maximum ramus breadth (MRL) in the MEX sample. The XIG sample displayed more pronounced sexual dimorphism with longer mandibles, higher and elongated chins than the MEX sample. Differences between sexes were observed only in the height of the mandibular body (HML), the distance from the foramen to the chin (MFA), and the mandibular length (MLT) in the XIG sample.

In our study, the male MAN values in the Girê Kortikê/medieval Kurdish population were significantly higher than those of the XIG and MEX populations. However, female MAN values in the Girê Kortikê/medieval Kurdish population were comparable to the XIG and MEX populations. The difference in mean MAN when comparing males and females in the Girê Kortikê population was significant. The divergences in MAN measurements between the medieval Kurdish population in Girê Kortikê and other populations could be linked to varying environmental, biological, and economic conditions in the regions these populations inhabit.

Our literature survey included data from measurements within China and non-Han Chinese populations, revealing average MAN values for 96 males and 107 females to be 123.44 $\pm$ 5.95 mm and 126.65 $\pm$ 5.64 mm, respectively [31]. The average male MAN measurement in the Girê Kortikê/medieval Kurdish population significantly surpassed the corresponding mean of the non-Han Chinese population. Conversely, the female MAN average in the Girê Kortikê/medieval Kurdish population was markedly lower than that in the non-Han Chinese population.

In reference to a study by Sharma et al. [33], the average male MAN value in India was 124.00 $\pm$ 6.27 mm, significantly different from the corresponding mean in the Girê Kortikê/medieval Kurdish male population. For Indian adult females, the average MAN was 124.03 $\pm$ 5.30 mm, similar to the female MAN mean in the Girê Kortikê/medieval Kurdish population.

Furthermore, MAN measurements were studied in the Italian population [5], yielding an average male MAN value of 122.00 $\pm$ 8.00 mm and a female average of 125.00 $\pm$ 6.00 mm. In the Girê Kortikê/medieval Kurdish population, the male MAN was significantly higher than the Italian population's average. However, the female MAN in the Girê Kortikê/medieval Kurdish population mirrored that of Italian women.

The disparities observed between male and female mandibles in our research can be attributed to various factors such as genetic predispositions, local influences, physical labor, nutrition accessibility, age at death, degree of the teeth attrition, among others. This allowed us to discern variations between average measurement values and mandible measurement parameters across different populations [34–36]. Nonetheless, research involving subjects from the medieval Kurdish population in Girê Kortikê remains scarce, indicating a need for more comprehensive and representative studies, potentially comparing panoramic radiographs with direct mandibular bone measurements from the Girê Kortikê's medieval Kurdish population.

However, we recognize the limitations of our study, including a relatively small sample size from the medieval Kurdish population in Girê Kortikê, especially for female mandibles.

While the study provides valuable insights into the sexual dimorphism of mandibles within the medieval Kurdish population of Girê Kortikê, several limitations are identified that could potentially affect the study's generalizability and interpretation of results. The most pronounced limitation is the sample size and its uneven gender distribution. The study includes 121 mandibles, with 55 from women and 66 from men. This imbalance may introduce bias in the results, possibly skewing the overall findings towards the over-represented sex. Future research should aim to include a larger, equal number of male and female participants to produce a more balanced and representative sample, thus ensuring a more accurate interpretation of sex-based differences.

Additionally, the study focuses solely on a medieval Kurdish population from a specific geographical region, Girê Kortikê. This can potentially limit the study's applicability to other populations, historical periods, or geographical regions, given the potential impact of various local influences such as genetic factors, lifestyle, diet, and environment on the mandibular characteristics.

The research's limited scope neglects the exploration of other aspects that could impact the mandibular morphology, such as genetic predispositions, local environmental factors, and the availability of nutrition. These variables can significantly influence the development and manifestation of sexual dimorphism in the mandible. Therefore, future investigations should incorporate these considerations to fully exploit the potential of the mandible in forensic and anthropological studies.

Lastly, the lack of cross-validation of the methods employed in this study could potentially limit its replicability. Ensuring that different methods produce consistent findings can increase the confidence in results and allow for more accurate interpretations and conclusions. Future research should aim to validate these findings using various methodologies and potentially different sample populations.

5. Conclusion

The information gained during this study can contribute to characterizing the male and female mandibles in the medieval Kurdish population of Girê Kortikê. Our investigation of mandibles highlighted no correlation between the height of the mandibular body (HML) and the length of the mandible (MLT) across sexes. A significant distinction in the size of the mandibular angle (MAN) between sexes suggest about possible specific feature of the Girê Kortikê/medieval Kurdish population to be clarified in additional study to achieve a comprehensive and in-depth evaluation of human remains within this specific region.

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Ethical statement

Under Turkish law, there is no necessity for ethical committee approval when it comes to archaeological and historical specimens. Additionally, the Faculty of Medicine at Dicle University has secured all the required permissions to conduct research with the specimens from the Diyarbakir Museum.

CRediT authorship contribution statement

Vatan Kavak: Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Project administration, Writing – original draft, Writing – review & editing. **Mara Pilmane:** Funding acquisition, Supervision, Validation, Writing – review & editing. **Dzintra Kazoka:** Data curation, Validation, Writing – review & editing. **Edgars Edelmers:** Validation, Visualization, Writing – review & editing. **Omer Satici:** Conceptualization, Software.

Declaration of competing interest

The authors declare no conflict of interest.

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