Sexual dimorphism based on metric and non-metric parameters of human teeth in a Brazilian population

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KEYWORDS

Forensic Anthropology,
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ABSTRACT

In forensic contexts, incomplete or fragmented bones are frequently encountered due to post-mortem damage and taphonomic changes, and teeth can be considered a valid and reliable source for sex estimation, as they are among the most resistant structures of the human body. Methods based on metric and non-metric dental traits are commonly used for sex estimation. The aim of this study was to evaluate the presence of sexual dimorphism in a Brazilian population through metric and non-metric analysis of teeth. A total of 73 individuals aged between 18 and 25 years were evaluated. All analyses were conducted on the upper jaw. The metric analysis consisted of obtaining buccolingual and mesiodistal measurements of the clinical crown of the teeth. In addition to measurements for each tooth, the maxillary dental arch perimeter and intercanine distance were also considered. The non-metric analysis consisted of observing and describing traits present or absent in the teeth, using the ASUDAS. Intraobserver error was assessed using the paired t-test and the Dahlberg method. Parametric or non-parametric tests were applied according to the data distribution. The mesiodistal and buccolingual dimensions proved effective for identifying sex differences, except for teeth 12/22 (mesiodistal) and 13/23 (buccolingual). The maxillary dental arch perimeter and intercanine distance were significantly larger in males. Regarding non-metric traits, the results were less significant; only a few teeth presented traits associated with sexual dimorphism: the lingual tubercle (tooth 22), the mesial marginal ridge tubercle (tooth 26), and the hypocone cusp (teeth 17 and 27). It is concluded that the findings, although relevant, should be interpreted with caution, as their consistency still needs to be confirmed. Therefore, additional studies with larger samples from different regions of Brazil are necessary to validate these parameters and consider them reliable in anthropological and forensic contexts.

INTRODUCTION

Forensic Anthropology is dedicated to the examination of human remains, with the intention of reconstructing the biological profile,[1] which encompasses a set of biological characteristics such as sex, age at death, population affinity, and stature.[2-4] The purpose is to narrow down the list of missing persons and, consequently, assist in the identification process.[1,2,5]

In anthropological analyses, sex estimation is fundamental.[1,6,7] It is necessary to apply tests to estimate other parameters of the biological profile[8] and, being based on sexual dimorphism, yields a dichotomous outcome (male or female).[5,8] Among all bones, the pelvis exhibits the highest degree of sexual dimorphism, followed by the long bones and the cranium.[8] In forensic scenarios, however, incomplete or fragmented bones are frequently encountered due to postmortem damage and taphonomic alterations.[1,6]
Teeth can be considered a valid and reliable source for sex estimation[1] as they exhibit sexual dimorphism[9] and are among the most resistant structures of the human body.[5,6,9] Their lower susceptibility to physical, chemical, and biological influences compared to bones provides greater postmortem durability,[1,6,9] which explains why, in many cases, they may be the only preserved structures.[10]
Methods based on both metric and non-metric dental traits are used for sex estimation.[11,12] Among the metric approaches, analyses of the buccolingual (BL) and mesiodistal (MD) dimensions of the tooth crowns[1,10,11,13] as well as intercanine distance (ICD),[13] are noteworthy. In addition, the maxillary dental arch perimeter (MDAP) can also be assessed as a complementary variable for sex discrimination.[14,15] Non-metric analyses evaluate tooth morphology and consider individual phenotypic variations,[10] which can be observed in the roots and crowns of all teeth.[11,16]
The most important and widely used systematization in dental morphology is the Arizona State University Dental Anthropology System (ASUDAS), proposed by Turner *et al.* in 1991.[17] It was developed to assess population affinity and is based on textual definitions of non-metric morphological traits, which can be simply observed and recorded.[17] These traits undergo minimal changes due to physiological dental wear, show considerable distinction among different populations, but exhibit low sexual dimorphism.[17] However, morphological discrepancies have been reported when comparing male and female teeth.[11,12]
Therefore, considering that teeth are among the most resistant structures of the human body and also exhibit sexual dimorphism,[9] particularly regarding their dimensions,[10] it becomes essential to evaluate the applicability of metric dental methods in different populations for sex estimation. Furthermore, the use of dental morphological traits included in the ASUDAS for sex estimation remains scarcely explored, highlighting the need to investigate their discriminative potential.
This study aimed to assess the presence of sexual dimorphism in a Brazilian population through metric and non-metric analyses (ASUDAS) of permanent teeth.

MATERIALS AND METHODS

A total of 73 individuals were assessed, including 33 males and 40 females, aged between 18 and 25 years. All participants were Brazilian, with ancestors up to the second degree also of Brazilian origin, and born in municipalities located in the South-Southwest mesoregion of the state of Minas Gerais, as established by the Brazilian Institute of Geography and Statistics (IBGE).[18]
All analyses were conducted on the upper jaw. Volunteers were clinically evaluated to verify whether they met the inclusion criteria for the study. To be included, all volunteers had to be fully dentate (excluding third molars) and free of anomalies, fractures, wear, or restorations on the teeth that could compromise the planned analyses. Volunteers were excluded if they were not born in, or did not have ancestors from, the regions under study; if they had missing teeth other than third molars; or if any morphological or structural alterations were clinically observed in the maxillary dental arch elements that could compromise the analyses.
Next, the sex of the volunteers was recorded, and dental impressions were taken using type II alginate to obtain plaster models. The models were then cast in type III dental stone, and both metric and non-metric analyses were performed on these models.

Metric analysis

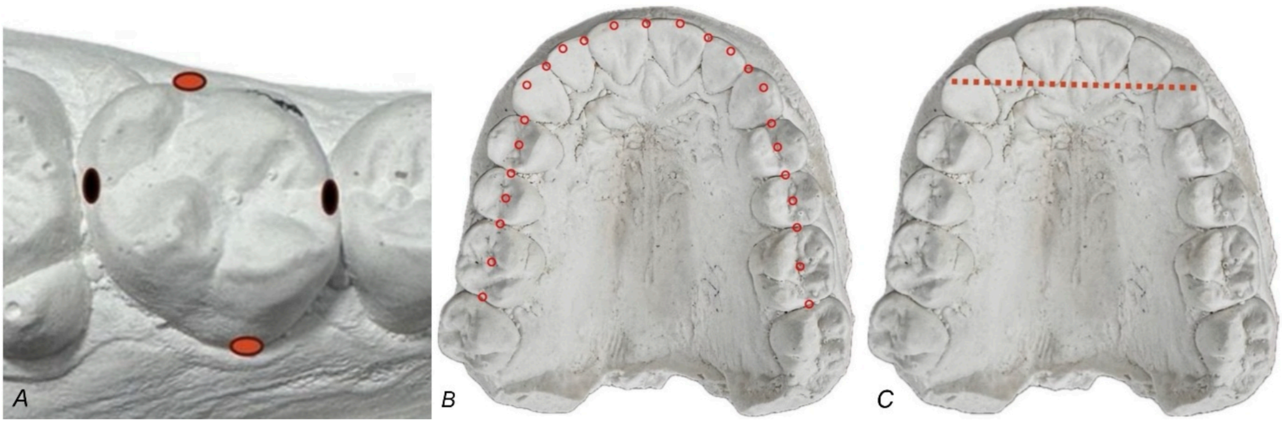
Metric analysis consisted of obtaining the BL and MD measurements of the clinical crowns of teeth 11 (right maxillary central incisor) and 21 (left maxillary central incisor), 12 (right maxillary lateral incisor) and 22 (left maxillary lateral incisor), 13 (right maxillary canine) and 23 (left maxillary canine), 16 (right maxillary first molar) and 26 (left maxillary second molar), and 17 (right maxillary second molar) and 27 (left maxillary second molar).

The MD measurement was obtained at the incisal third of the proximal surfaces of the incisors and canines (proximal ridges) and at the occlusal third of the proximal surfaces of the molars, at the greatest distance between the marginal ridges (proximal ridges). The BL measurement was taken at the cervical third of the tooth crown, at the region of greatest convexity of the free surfaces, that is, at the buccal and lingual ridges (Fig. 1).

In addition to the measurements of each tooth, the MDAP and ICD were also considered. The dental arch perimeter (Fig. 1) is defined as the distance from the central point of the distal marginal ridge of the right maxillary first molar to the same point on the distal marginal ridge of the left maxillary first molar, passing through the center of the occlusal surface (central fossae) of the posterior teeth and the incisal edges of the anterior teeth.[19] The ICD corresponds to the straight-line distance between the crown apex (cusp) of the right and left canines.

All measurements were performed by a single researcher on two occasions, with a fifteen-day interval, using a digital caliper with hundredth-millimeter precision (Marberg®, Marberg Ferramentas, Brazil). The MDAP was measured using a silk thread positioned along the reference points described above, and the value was subsequently obtained with the caliper. The ICD (Fig. 1) was measured directly with the caliper.

Figure 1. A – Representation of the sites where measurements of each dental element were obtained. BL – distance between the orange points; MD – distance between the black points. B – Maxillary Dental Arch Perimeter (MDAP); red points extending from the center of the distal marginal ridge of tooth 16 to the center of the distal marginal ridge of tooth 26, passing through the centers of the occlusal surfaces and incisal edges. C – Representation of the Intercanine Distance (ICD), measured between the cusp apices of teeth 13 and 23.



Non-metric analysis

Non-metric analysis consisted of observing and recording the presence or absence of traits in the teeth. For this purpose, the Arizona State University Dental Anthropology System (ASUDAS)[17] was used. Although one trait analyzed is not included in this system, it corresponds to the presence or absence of the Bolk tubercle or paramolar tubercle (on the buccal surface of the mesiobuccal cusp of the maxillary second molar). All observations were performed using a five-times magnification loupe and following the ASUDAS guidelines, with adequate and sufficient lighting. Two observations were also conducted by a single observer, with a fifteen-day interval between them, to avoid any interference in decision-making.

The following traits were observed: in the maxillary central incisors: a) shoveling – presence of lingual marginal ridges; b) double shoveling – presence of buccal marginal ridges; c) cingulum – presence of one or more lingual tubercles extending from the cingulum to the lingual fossa; and d) interruption grooves – vertical grooves crossing the dental cingulum. In the maxillary lateral incisors: a) morphology – peg-shaped incisor (“reptilian” incisor); diminutive incisor – reduced crown dimensions; tri-form – a narrow projection of the cingulum extending toward the incisal edges, forming a “T” shape in incisal view; barrel-shaped – marginal ridges fold lingually and coalesce; normal-shaped – conventional morphology of a maxillary lateral incisor; b) agenesis – congenital absence; c) cingulum – presence of lingual tubercles extending from the cingulum to the lingual fossa; and d) interruption grooves – vertical grooves crossing the dental cingulum. In the maxillary first molars: a) hypocone – presence or absence of the distolingual cusp; b) Carabelli tubercle – visible on the mesiolingual cusp; c) distal accessory tubercle (metaconule) – present on the distal marginal ridge; and d) mesial tubercles – present on the mesial marginal ridge. In the maxillary second molars: a) hypocone (distolingual cusp) – presence or absence; b) Carabelli tubercle – visible on the mesiolingual cusp; c) distal accessory tubercle (metaconule) – present on the distal marginal ridge; d) mesial tubercles – present on the mesial marginal ridge; and e) Bolk tubercle – paramolar cusp, present on the buccal surface of the mesiobuccal cusp. Each of the traits observed was classified according to the ASUDAS, considering the teeth on the right and left sides separately. As previously mentioned, the analysis of the paramolar cusp or Bolk tubercle, although not included in the ASUDAS, is reported in the literature[20] and was therefore considered in this study.

Statistical analysis

Statistical analysis of the data was performed using Jamovi software, version 2.3.28 (The Jamovi Project, Australia). The normality of the metric variables was assessed with the Shapiro–Wilk test. For those with normal distribution, Student's *t*-test for independent samples was applied; in the absence of normality, the nonparametric Mann–Whitney test was used. Qualitative (non-metric) variables were described and compared using Fisher's exact test. All analyses adopted a significance level of 5% ($p < 0.05$).

Intra-observer systematic error was assessed using the paired *t*-test, while random error was estimated using the method proposed by Dahlberg, according to the formula:

$$\text{error}^2 = \frac{d2}{2n}$$

where d represents the difference between two measurements and n the number of volunteers evaluated.

RESULTS

Intra-observer systematic error, assessed using the paired *t*-test, showed no significant differences ($p > 0.05$). Intra-observer casual error, evaluated using Dahlberg's method, presented values below 1 mm for all measurements (Table 1).

Table 1. Dahlberg test values for the two measurements performed by the same observer.

Measurement	Male	Female
BL 11	0.23	0.24
BL 21	0.33	0.44
BL 12	0.24	0.34
BL 22	0.54	0.48
BL 13	0.15	0.30
BL 23	0.17	0.29
BL 16	0.26	0.39
BL 26	0.22	0.49
BL 17	0.31	0.47
BL 27	0.35	0.68
MDAP	0.30	0.81
ICD	0.18	0.73
MD 11	0.10	0.25
MD 21	0.17	0.26
MD 12	0.17	0.55
MD 22	0.25	0.28
MD 13	0.18	0.22
MD 23	0.16	0.31
MD 16	0.28	0.34
MD 26	0.34	0.33
MD 17	0.27	0.38
MD 27	0.32	0.34

BL – buccolingual; MD – mesiodistal; MDAP – maxillary dental arch perimeter; ICD – intercanine distance. Values should be < 1.0.

Metric analysis

BL, MD, MDAP, and ICD measurements were analyzed according to the data distribution.

For the BL measurement, teeth 11, 12, 22, 13, 23, 16, and 26, which showed a normal distribution, were analyzed using the independent samples Student's t-test. For teeth 21, 17, and 27, which did not show normality, the nonparametric Mann-Whitney test was applied (Table 2).

The BL measurements were statistically significant between sexes (Table 2), with the exception of the right and left canines, which did not differ between the groups analyzed. However, for tooth 13, no significant difference was observed between sexes, although the p-value (0.053) approached the established significance level (0.05). Fig. 2 shows the means and medians of the BL distances for each tooth and sex, providing a visual illustration of the results.

Similar results were observed for the MD measurements of the analyzed teeth. Statistically significant differences between sexes were found for most teeth, except for the maxillary lateral incisors, in which no sexual dimorphism was detected based on MD dimension. Table 3 presents the mean MD measurements and the statistical results. As normality was not observed for teeth 11, 13, 23, 17, and 27, the Mann–Whitney test was applied. Mean values were higher in males for all evaluated teeth. Fig. 3 shows the means and medians of the MD distances for each tooth and sex, providing a visual illustration of the results.

For the MDAP and ICD, Shapiro–Wilk test values indicated normality of the distributions of these measurements ($p > 0.05$). Analysis using Student's t-test revealed statistically significant differences between sexes ($p < 0.001$), with higher values in males, indicating that these linear measurements can be used for sex estimation (Table 4). Fig. 4 shows the means and medians of MDAP and ICD measurements for each sex, providing a visual illustration of the results.

Table 2. Buccolingual (BL) distance values for male and female

Tooth	Sex	Mean	Shapiro-Wilk(p)	Student's t-test(p)	Mann-Whitney(p)
11	Male	7.77	0.05	< 0.001 *	-
	Female	7.16			
21	Male	7.72	0.03	-	< 0.001 *
	Female	7.13			
12	Male	6.96	0.09	< 0.001 *	-
	Female	6.41			
22	Male	6.95	0.10	< 0.001 *	-
	Female	6.38			
13	Male	8.36	0.17	0.053	-
	Female	8.17			
23	Male	8.32	0.09	0.119	-
	Female	8.16			
16	Male	11.80	0.29	0.003 *	-
	Female	11.50			
26	Male	11.80	0.10	< 0.001 *	-
	Female	11.30			
17	Male	11.40	< 0.001	-	< 0.001 *
	Female	11.00			
27	Male	11.30	0.006	-	< 0.001 *
	Female	10.90			

According to the Shapiro-Wilk test, data with $p > 0.05$ are considered normally distributed; $p < 0.05$ indicates non-normality. p-values < 0.05 for the Student's t-test and Mann-Whitney test correspond to statistically significant results (*).

Figure 2. Graphical representation of the mean and median of the BL measurement

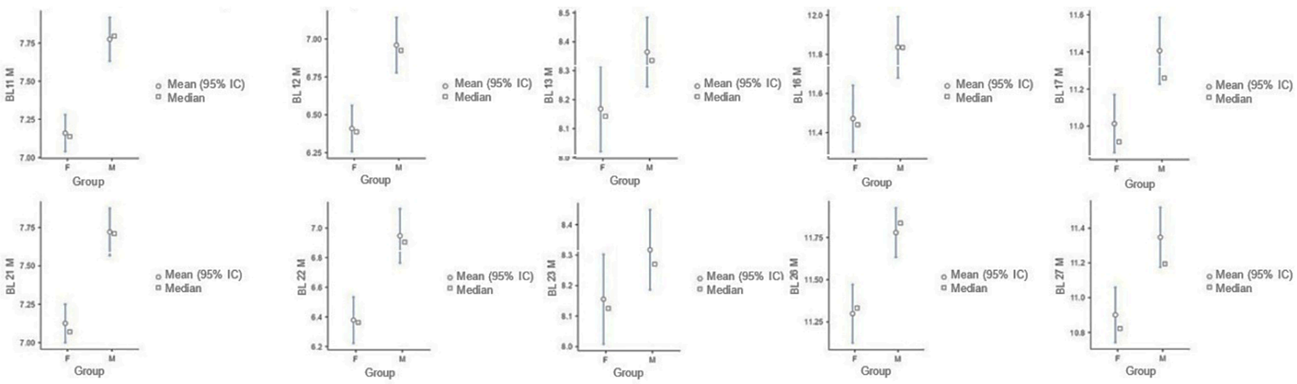


Table 3. Mesiodistal (MD) distance values for males and females.

Tooth	Sex	Mean	Shapiro-Wilk(p)	Student's t-test(p)	Mann-Whitney(p)
11	Male	9.00	0.028	-	0.006 *
	Female	8.71			
21	Male	8.97	0.087	0.009 *	-
	Female	8.65			
12	Male	6.94	0.069	0.892	-
	Female	6.93			
22	Male	6.96	0.100	0.224	-
	Female	6.82			
13	Male	8.10	< 0.001	-	< 0.001 *
	Female	7.73			
23	Male	8.08	< 0.001	-	< 0.001 *
	Female	7.71			
16	Male	10.90	0.893	< 0.001 *	-
	Female	10.07			
26	Male	10.90	0.891	< 0.001 *	-
	Female	10.00			
17	Male	10.60	0.048	-	< 0.001 *
	Female	9.83			
27	Male	10.50	0.014	-	< 0.001 *
	Female	9.77			

According to the Shapiro-Wilk test, data with $p > 0.05$ are considered normally distributed; $p < 0.05$ indicates non-normality. p-values < 0.05 for the Student's t-test and Mann-Whitney test correspond to statistically significant results (*).

Figure 3. Graphical representation of the mean and median of the MD measurement

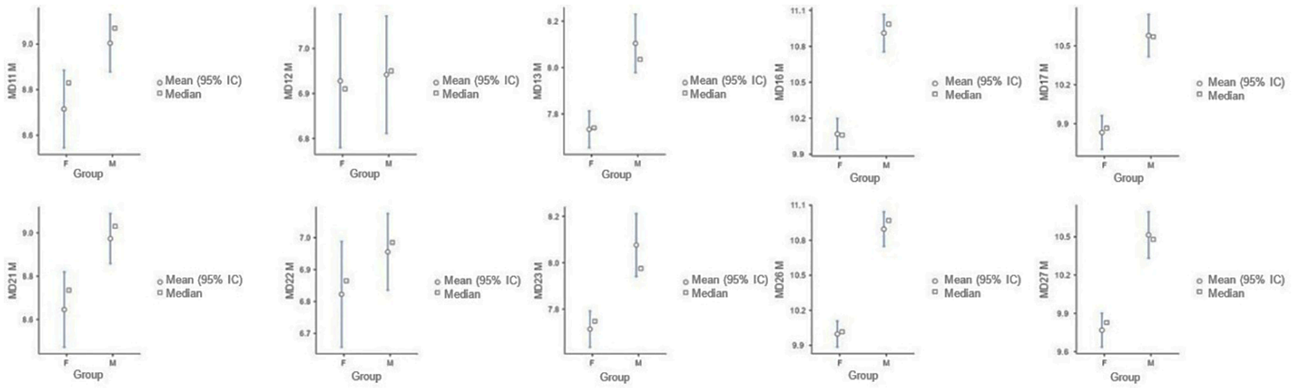
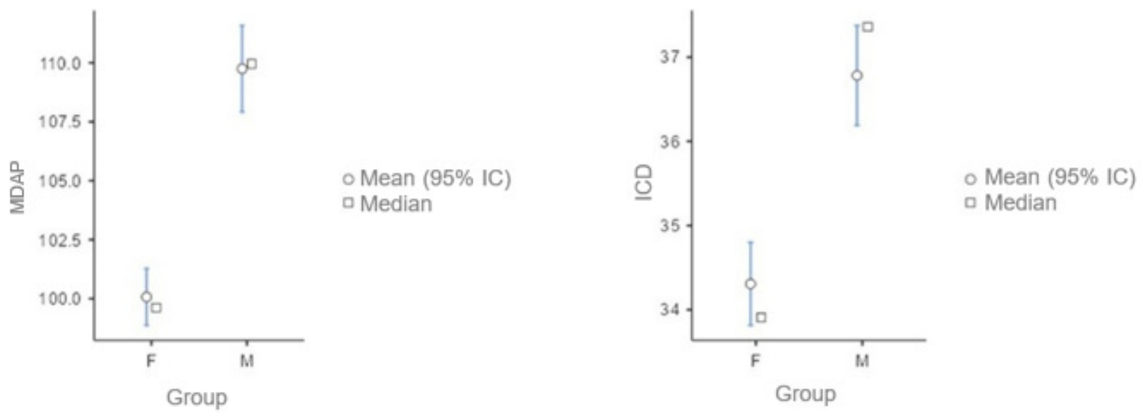


Table 4. Values of the maxillary dental arch perimeter (MDAP) and Intercanine Distance (ICD) measurements for males and females.

Measurements	Sex	Mean	Shapiro-Wilk(p)	Student's t-test (p)
MDAP	Male Female	109.8 100.1	0.278	< 0.001 *
ICD	Male Female	36.8 34.3	0.876	< 0.001 *

According to the Shapiro-Wilk test, data with $p > 0.05$ are considered normally distributed; $p < 0.05$ indicates non-normality. p-values < 0.05 for the Student's t-tests correspond to statistically significant results (*).

Figure 4. Graphical representation of the mean and median of MDAP and ICD measurements



Non-metric analysis

Morphologically, using parameters established by the ASUDAS[17] and Fisher's exact test, some statistically significant differences were observed for differentiating male and female sexes. Fig. 5 shows some of the morphological traits evaluated in the permanent maxillary incisors, according to the ASUDAS.[17] Considering the maxillary central incisors, evaluated through non-metric traits, no significant differences were observed between sexes. For the maxillary lateral incisors, a significant difference was found in the number of lingual tubercles of tooth 22, which were more frequent in males. Tables 5 and 6 present the descriptive values of the morphological analysis of the permanent maxillary incisors, as well as the p-values obtained from Fisher's exact test. Fig. 6 shows some of the morphological traits analyzed in the permanent maxillary molars, according to the ASUDAS.[17] In the maxillary first molars, significant differences were observed in the number of mesial marginal ridge tubercles only for tooth 26 (p = 0.001), being more frequent in males. In the maxillary second molars, on both the right and left sides, significant differences were found regarding the presence of the hypocone (distolingual cusp), also more frequent in males. Tables 7 and 8 present the descriptive values of the morphological analysis of the permanent maxillary molars, as well as the *p*-values obtained from Fisher's exact test.

Figure 5. A – Representation of the shoveling trait on the lingual (palatal) surface of the maxillary incisors: grade 0. B – Shoveling scoring 1. C – Shoveling scoring 2. D – Black arrows indicate lingual tubercles on teeth 11 and 21, and the red arrow indicates the interruption groove on tooth 22. E – Lingual tubercles and marginal ridges outlined on teeth 12, 11, 21, and 22.

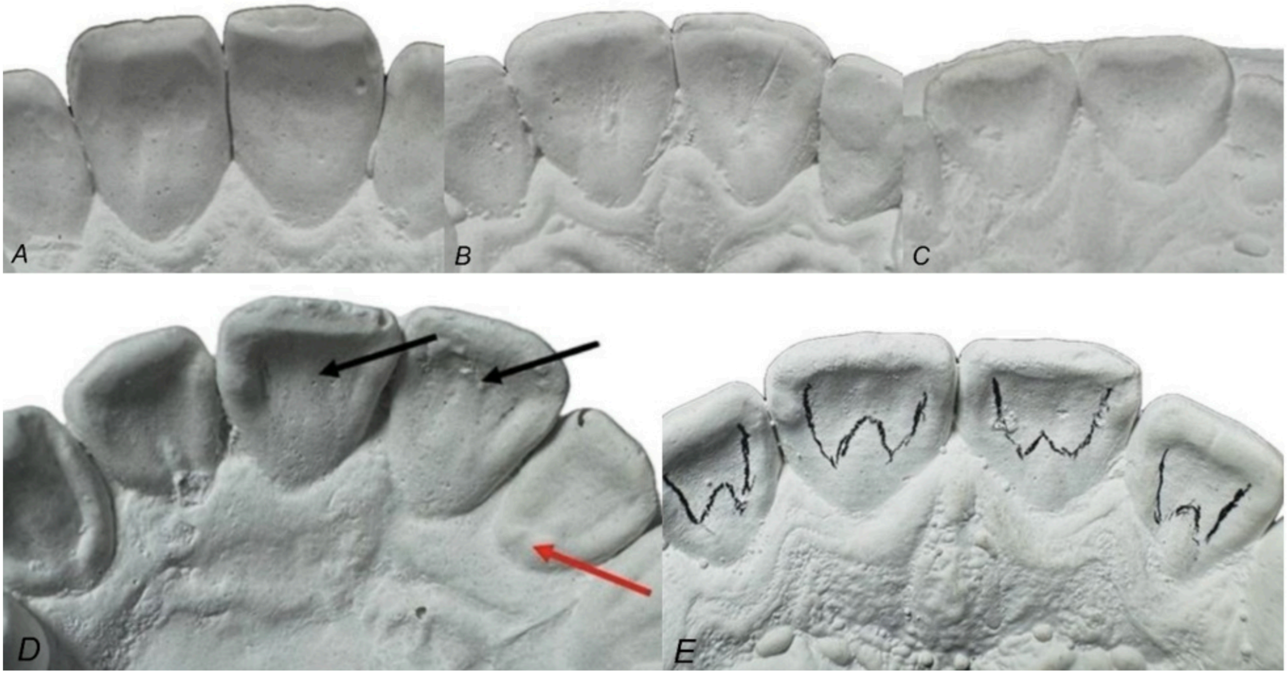


Table 5. Morphological data for the permanent maxillary central incisors

Morphological trait	11 Male	11 Female	21 Male	21 Female
Shoveling 0	0	0	0	0
Shoveling 1	25 (75.8%)	29 (72.5%)	25 (75.8%)	29 (72.5%)
Shoveling 2	8 (24.2%)	11 (27.5%)	8 (24.2%)	11 (27.5%)
Shoveling 3	0	0	0	0
p(Fisher)	0.79		0.79	
Double shoveling	0	0	0	0
p(Fisher)	-		-	
Absent tubercle	20 (60.6%)	30(75.0%)	20 (60.6%)	32 (80.0%)
01 tubercle	5 (15.1%)	8 (20.0%)	8 (24.3%)	5 (12.5%)
02 tubercle	8 (24.3%)	2 (5.0%)	5 (15.1%)	3 (7.5%)
03 tubercle	0	0	0	0
p(Fisher)	0.07		0.20	

The double shoveling trait was not observed in any tooth; therefore, comparative statistics could not be calculated. Significant values with $p < 0.05$.

Table 6. Morphological data for the permanent maxillary lateral incisors

Morphological trait	12 Male	12 Female	22 Male	22 Female
Peg shaped	0	0	0	0
Diminute	0	0	0	1 (2.5%)
Tri-form	0	0	0	0
Barrel form	0	0	0	0
Normal shaped	33 (100%)	40 (100%)	33 (100%)	39 (97.5%)
p(Fisher)	1.00		1.00	
Agenesis	0	0	0	0
p(Fisher)	-		-	
Absent tubercle	17 (51.5%)	29(72.5%)	17 (51.5%)	32 (80.0%)
01 tubercle	16 (48.5%)	11 (27.5%)	16 (48.5%)	8 (20.0%)
02 tubercle	0	0	0	0
03 tubercle	0	0	0	0
p(Fisher)	0.08		0.01*	
Interruption groove present	13 (40.0%)	8 (20.0%)	13 (40.0%)	9 (22.5%)
Interruption groove absent	20 (60.0%)	32 (80.0%)	20 (60.0%)	31 (77.5%)
p(Fisher)	0.07		0.13	

The agenesis trait was not observed in any tooth; therefore, comparative statistics could not be calculated. Significant values with $p < 0.05$ (*).

Figure 6. A – Carabelli tubercle (arrow) present on the mesiopalatal cusp of tooth 16. B – Tooth 27 exhibiting three cusps, with absence of the hypocone. The arrow indicates a distal tubercle on the distal marginal ridge of tooth 27. C – Presence of distal tubercles on tooth 17 (arrow). D – Arrows indicate tubercles located on the mesial marginal ridges of teeth 26 and 27. E – Paramolar tubercle (Bolk's tubercle); the arrow points to the tubercle located on the buccal surface of the mesiobuccal cusp of tooth 27

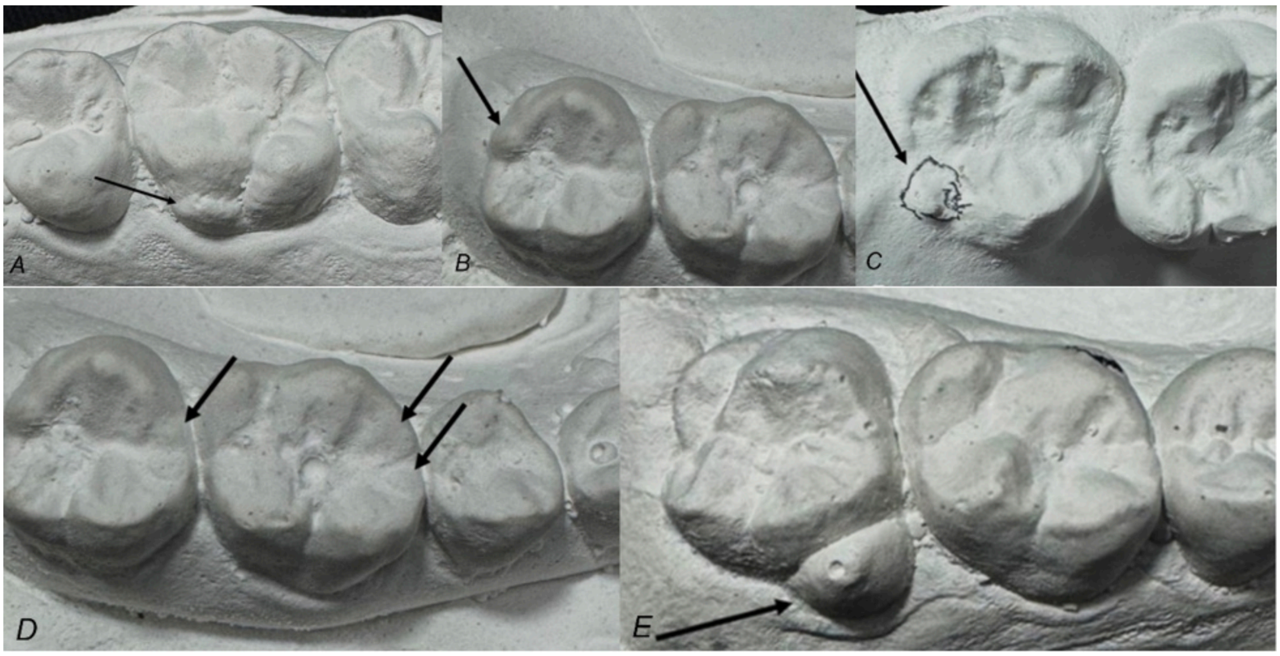


Table 7. Morphological data for the permanent maxillary first molars

Morphological trait	16 Male	16 Female	26 Male	26 Female
Hypocone present	33 (100.0%)	40 (100%)	33 (100%)	40 (100%)
Hypocone absent	0	0	0	0
p (Fisher)	1.00		1.00	
Carabelli tubercle absent	1 (3.0%)	1 (2.5%)	1 (3.0%)	2 (5.0%)
Carabelli tubercle I/II	16 (48.5%)	19 (47.5%)	15 (45.5%)	19 (47.5%)
Carabelli tubercle III/IV	8 (24.3%)	10(25.0%)	11 (33.3%)	8 (20.0%)
Carabelli tubercle V/VI	8 (24.2%)	10 (25.0%)	6 (18.2%)	11 (27.5%)
Carabelli tubercle VII	0	0	0	0
p(Fisher)	1.00		0.58	
Distal tubercle present	4 (12.2%)	10 (25.0%)	4 (12.2%)	13 (32.5%)
Distal tubercle absent	29 (87.8%)	30 (75.0%)	29 (87.8%)	27 (67.5%)
p(Fisher)	0.23		0.05	
Mesial tubercle absent	3 (9.1%)	11 (27.5%)	5 (15.2%)	22 (55.0%)
01 mesial tubercle	21 (63.7%)	23 (57.5%)	22 (66.7%)	18 (45.0%)
02 mesial tubercles	6 (18.1%)	6 (15.0%)	6 (15.0%)	0
03 mesial tubercles	3 (9.1%)	0	0	0
p(Fisher)	0.06		<0.001*	

Significant values with $p < 0.05$ (*).

Table 8. Morphological data for permanent maxillary second molars

Morphological trait	17 Male	17 Female	27 Male	27 Female
Hypocone present	30 (90.9%)	24 (60.0%)	28 (84.8%)	24 (60.0%)
Hypocone absent	3 (9.1%)	16 (40.0%)	5 (15.2%)	16 (40.0%)
p (Fisher)	0.003*		0.022*	
Carabelli tubercle absent	25 (75.7%)	33 (82.5%)	26 (78.8%)	33 (82.5%)
Carabelli tubercle I/II	7 (21.2%)	5 (12.5%)	7 (21.2%)	5 (12.5%)
Carabelli tubercle III/IV	1 (3.1%)	2 (5.0%)	0	2 (5.0%)
Carabelli tubercle V/VI	0	0	0	0
Carabelli tubercle VII	0	0	0	0
p(Fisher)	0.57		0.45	
Distal tubercle present	13 (39.4%)	13 (32.5%)	8 (24.2%)	15 (37.5%)
Distal tubercle absent	20 (60.6%)	27 (67.5%)	25 (75.8%)	25 (62.5%)
p(Fisher)	0.62		0.31	
Mesial tubercle absent	10 (30.3%)	17 (42.5%)	18 (54.5%)	22 (55.0%)
01 mesial tubercle	18 (54.6%)	20 (50.0%)	15 (45.5%)	13 (32.5%)
02 mesial tubercles	5 (15.1%)	3 (7.5%)	0	5 (12.5%)

03 mesial tubercles	0	0	0	0
p(Fisher)	0.41		0.08	
Paramolar tubercle present	0	0	1 (3,3%)	0
Paramolar tubercle absent	33 (100%)	40 (100%)	32 (96.7%)	40 (100%)
p(Fisher)	1.0		0.45	

Significant values with $p < 0.05$ (*).

DISCUSSION

The study and analysis of teeth provide essential information for establishing an individual's biological profile.[6] Among the characteristics of this profile, sex estimation is of great importance, particularly for classifying individuals into the two main groups, male and female.[5,8] Therefore, this study was conducted to establish data regarding the BL and MD measurements of dental elements, the MDAP, and ICD in permanent maxillary teeth in a Brazilian population, in addition to non-metric dental traits.

There is evidence that tooth size is influenced by sex chromosomes,[5,21] with male teeth generally being larger than female teeth.[1] The results obtained in this study, shown in Tables 2 and 3, are consistent with this assertion, as most BL measurements exhibited significant differences between sexes, with the exception of the canines. Similarly, marked differences were observed in MD dimensions, except for the maxillary lateral incisors, reinforcing the influence of biological factors on dental sexual dimorphism.

Alanazi *et al.* (2022)[22] analyzed morphometric parameters of permanent canines in an Arab population and observed that sexual dimorphism can be detected through MD and BL dimensions. However, in the present study, considering the BL measurement and focusing on the maxillary canines, the data differ, as no differences between sexes were found (Table 2). On the other hand, supporting the previous authors regarding MD measurement, the maxillary canines do exhibit sexual dimorphism (Table 3). Specifically, for the right maxillary canine (tooth 13), the p-value (0.053) for the BL measurement approached the significance threshold (0.05), suggesting a trend, but without a statistically significant difference. These findings also diverge from other studies,[23,24] which indicate that all dimensions of the maxillary canines may contribute to sex estimation. One possible explanation for this discrepancy may be related to sample size or specific characteristics of the population analyzed.

Abaid *et al.* (2021)[25] also reported sexual dimorphism based on MD dimensions for almost all teeth in a population of Australian adolescents, with the exception of the maxillary second premolars, which showed no differences between sexes. Other authors support these findings, showing greater MD dimensions in male teeth compared to female teeth.[14,24] As shown in Table 3, the results of this study, although the premolar group was not analyzed, also indicate the potential for sex estimation for almost all dental elements based on MD measurements; only the maxillary lateral incisors did not show differences between males and females. However, in those teeth that did show differences, male teeth exhibited greater dimensions.

Although most studies on metric analysis of teeth primarily focus on anterior teeth (incisors and canines), with canines considered the most reliable for detecting sexual dimorphism due to their larger dimensions in males, posterior teeth, including molars, can provide highly relevant information for sex estimation.[5,26,27] In this study, MD and BL measurements of the permanent first and second maxillary molars were evaluated, and sexual dimorphism was observed for both measurements, with males exhibiting larger dimensions than females.

When considering the ICD, that is, the distance between the apices of the cusps of these teeth, the results showed that ICD in males is significantly greater than in females (Table 4). These findings differ from those reported by Selim *et al.* (2020),[24] who observed a greater ICD in females compared to males. This contrast in results may be due to the different methodology used by these authors—cone-beam computed tomography—or because their study involved a population from a different region of Brazil, unlike the population analyzed in the present study.

Mazumder *et al.* (2023)[14] and Ajmal *et al.* (2023)[28] report that the sum of MD measurements, resulting in the dental arch perimeter, is a very useful parameter for sex estimation. The present study showed that, based on isolated MD measurements, the maxillary lateral incisors do not exhibit sexual dimorphism; however, when the MDAP was analyzed considering all MD dimensions, the male maxillary dental arch was significantly larger than the female (Table 4). Thus, the findings suggest that metric analysis of the maxillary teeth, including MD, BL, MDAP, and ICD, can serve as a relevant auxiliary tool for biological sex estimation.

From the perspective of non-metric morphological aspects, there is phenotypic variation in both deciduous and permanent dentition, particularly across different population groups, and this variation can be assessed through the observation and description of various dental traits.[17,29] The ASUDAS[17] used in this study, allows a simplified recording of qualitative morphological traits that undergo minimal wear over time and are widely used to estimate an individual's population affinity, but are less frequently employed for observing sexual dimorphism, as they are considered less influenced by sex.[30] Nonetheless, this study showed that, despite the limited number of traits, differences between males and females can still be observed.

Moreover, some authors report that the traits analyzed in this system are extremely stable, with evolutionary changes occurring over thousands of years, and that the genetic factor influencing dental morphology is also highly stable.[31,32] Therefore, these traits are reliable for interindividual comparisons and could serve as an additional tool in human identification processes.

In the analysis of non-metric traits, it is essential to consider intra-observer error, since, despite technical rigor, a certain degree of subjectivity may exist.[17] In this study, observations were performed twice by the same examiner under standardized conditions, with the paired *t*-test applied to assess systematic error and Dahlberg's formula used for casual error. In both cases, the results remained below reference limits for error consideration. In this context, the absence of significant error between observations supports the reliability of the analysis, allowing the suggestion that sexual dimorphism is expressed in some dental morphological traits.

Thus, although the literature indicates that the ASUDAS is more suitable for population affinity estimation,[29] the data obtained for the left maxillary lateral incisor, left maxillary first molar, and both maxillary second molars show the presence of sexual dimorphism (Tables 6, 7 and 8). The presence of lingual tubercles extending into the lingual fossa of tooth 22 was more frequent in males than in females. The same pattern was observed for the mesial marginal ridge tubercles of tooth 26 and for the presence of the hypocone cusp in the right and left maxillary second molars, being more frequent in male individuals. Tinoco *et al.* (2016)[33] also reported sex differences based on the hypocone cusp of the maxillary second molar, in agreement with the results of this study; however, they also observed sexual dimorphism for the Carabelli tubercle, which was not found in the population analyzed in the present study.

Although only three traits, out of all those analyzed, showed significant differences between sexes, they could still be used as auxiliary tools for sex estimation, as they are easily observable and recordable. This limited number of distinguishing traits between the analyzed groups may be related to the sample size used in this study, but it is always important that the evaluation of qualitative characteristics be conducted on a sample that more adequately represents the population. Therefore, the importance of further studies on non-metric traits with larger and more robust samples is emphasized, in order to accurately establish which traits may exhibit sexual dimorphism.

Additionally, the paramolar tubercle was also analyzed, although it is not part of the ASUDAS criteria and occurs at low frequency in populations. It is considered an accessory cusp located on the buccal surface of the mesiobuccal cusp of the permanent maxillary second molars (paracone).[20,34] The data from this study are consistent with the literature reporting low frequency,[20,34] as only a single male individual presented this tubercle. On the other hand, some researchers, such as Kustaloghi (1962),[35] reported a high frequency in an Indian population, although without distinction between sexes.

Therefore, the results of this study suggest that metric traits and some non-metric characteristics of human permanent maxillary teeth provide evidence that can contribute to sex estimation, especially in situations where traditionally used structures, such as the pelvis and skull, are not available. In the absence of these elements, teeth can offer additional relevant information for sex differentiation, particularly when analyzed using quantitative data. Considering the small sample size, these findings should be interpreted with caution and regarded as indicative of the applicability of these methods in future studies.

CONCLUSION

The results of this study allow us to conclude that MD and BL measurements are effective for establishing sexual dimorphism. However, for teeth 12/22, the MD measurement did not show sexual dimorphism, and similarly, for teeth 13/23, the BL measurement did not indicate dimorphism. The MDAP and ICD were significantly greater in males than in females, suggesting that these parameters may serve as indicators for sex differentiation. Regarding non-metric analyses, in the studied population, the results were of limited significance, with only a few teeth presenting traits associated with dimorphism: the lingual tubercle on tooth 22, the mesial marginal ridge tubercle on tooth 26, and the presence of the hypocone cusp on teeth 17 and 27. Although these findings are relevant, they should be interpreted with caution, as their consistency still needs to be confirmed. Therefore, further studies with larger samples from different regions of Brazil are recommended to validate these parameters and consider them reliable in anthropological and forensic contexts.

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