A Radio-Odontometric Analysis of Sexual Dimorphism in First Molars Using Cone-Beam Computed Tomography

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Objective: Different techniques for sex prediction are developed and used in the forensic medicine field. One of these methods is based on the teeth morphometry. The aim of the present study was to evaluate the degree of sex determination of the maxillary and mandibular first molar teeth in cone beam computed tomography images.

Method and Materials: This study was carried out on cone beam computed tomography images of 100 men and 100 women with a mean age of 21.28 ± 2.47 years. The roof, floor and height of pulp chamber, as well as marginal enamel thickness and dentin thickness at the height of contour, tooth width, and crown length were measured. Student *t* test and discriminant analysis were applied to assess the differences in the measured parameters between men and women.

Results: According to the present study, the maxillary first molar was more dimorphic than the mandibular teeth. The accuracy of sex identification of mandibular and maxillary first molar tooth was 84% and 77%, respectively. The mesiodistal measured variables were more accurate in sexual differentiation than the buccolingual ones. For sex differentiation, the most dominant variables for maxillary and mandibular first molar teeth were crown height and dentin thickness, respectively.

Conclusions: The first molar tooth showed an acceptable level of sex determination accuracy based on the odontometric measurements.

Key Words: cone-beam computed tomography, sex dimorphism, molar tooth, odontometric, forensic science

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Sex differentiation is crucial in the identification of an individual in a medicolegal investigation. Previous studies have provided several methods for sex discrimination, including DNA analysis, morphological features of the bones and teeth.[1,2] The teeth are highly stable to mechanical, chemical, physical, and thermal insults; therefore, they are a potential source for sex determination when other anatomic structures no longer exist, and DNA tests are impossible.[3,4]

The sexual dimorphism of the first permanent molar is a controversial subject. Several studies have previously revealed a high level of sexual dimorphism for the first permanent molars,[5–7] whereas other researchers have not established such a result.[8,9] Conventional radiographic techniques provide information on the teeth in 2 dimensions. However, cone-beam computed tomography (CBCT) can produce 3-dimensional quantitative data on the tooth dimension, overcoming the conventional technique limitations, such as magnification, geometric distortion, superimposed structures, and inconsistent head position.[10–12] So far, the mesiodistal (MD) tooth dimension has been analyzed quantitatively by several studies based on 2D radiography or buccolingual (BL) dimension on the cast or teeth.[1,13–16] To the best of our knowledge, there is no study differentiating sex based on linear measurements of teeth using CBCT images.

The aim of the present study was to evaluate the degree of sex determination of the maxillary and mandibular first molar teeth in both MD and BL dimensions, using the odontometric parameters of these teeth in CBCT images.

MATERIALS AND METHODS

This cross-sectional study was approved by the institutional ethics committee. Among the patients referred to the oral and maxillofacial radiology department, the CBCTs of 200 patients, including 100 women and 100 men, between the age group of 15 to 25 years with the mean age of 21.28 ± 2.47 years were randomly collected for further analysis. Written consent had been taken at the time of radiographic examination from all the patients for probable use of their anonymous information in future researches. Exclusion criteria were the presence of oral pathologies, facial and oral deformities, and systemic diseases. The first molars with caries and attrition were excluded because they could interfere with the visualization and measurement of the parameters. Only sound and completely developed teeth with closed apices were taken into consideration. The CBCT images were taken using New Tom VGi with the following setting parameters: scan time, 8.9 seconds; 5 mA; 19 mAs; 120 kV. All CBCT images were taken by the same clinician.

To evaluate the tooth dimensions, the corrected sagittal and coronal slices were reconstructed with a slice thickness of 0.3 and a slice interval of 1 mm. On the center of the corrected sagittal and coronal sections, the roof, floor, and height of the pulp chamber, as well as the mesial and distal enamel thickness, dentin thickness at the height of contour (HOC), tooth width at the HOC (WH) and width at cervix (WC) and finally crown length of the upper and lower first molar teeth were measured accurately using CBCT software by an oral and maxillofacial radiologist who was blind to the sex of the patients (Figs. 1–3).

The radiographs, with a 2-week interval between data recording phases, were measured again by the same oral and maxillofacial radiologist to assess the significance of any errors during measurements. Subsequently, to determine the interoperator method error, the radiographs of 20 patients were randomly selected and measured again by another oral and maxillofacial radiologist. Intraobserver and interobserver agreements were assessed using the intraclass correlation coefficient.

Data were summarized using the mean ± standard deviation. Independent sample *t* test and discriminant analysis were used to assess the impact of the measurements on sexual dimorphism. All data were analyzed using IBM SPSS version 22.0 (SPSS

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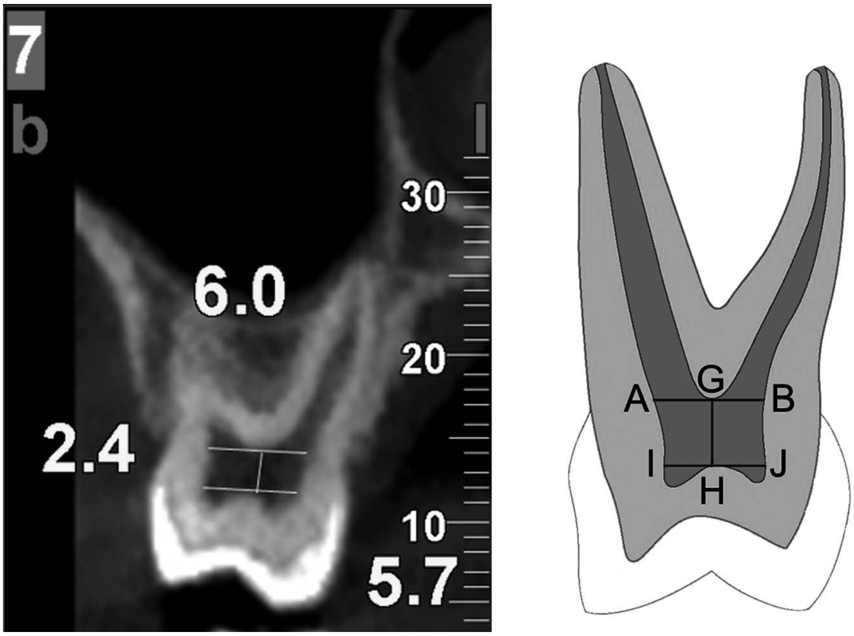

FIGURE 1. Measured variables on the maxillary tooth. IJ, pulp chamber roof; AB, pulp chamber floor; GH, pulp chamber height.

Inc, IBM Corporation, NY). A *P* value less than 0.05 was considered statistically significant.

RESULTS

All intraclass correlation coefficient values were higher than 0.80, indicating acceptable intraobserver and interobserver agreements for all the measurements. Table 1 shows the results for univariate comparisons of the measurements between the 2 sexes. In the MD aspect of the maxillary tooth, significantly higher mean values for WH, pulpal floor width (PFW), pulpal roof width (PRW), dentin thickness at the HOC (DH), and maximum crown height to cementoenamel junction (CH) were obtained for men than those for women. For the mandibular tooth, similar results were obtained only for WH, PRW, and DH. Moreover, WC had a higher mean in men in comparison with women in this jaw. In the BL aspect, mean WH, DH, and CH were significantly higher in men compared with those measured variables for women. Moreover, men had higher mean for PFW and pulpal chamber height (PH) in the maxillary tooth, as well as a higher mean for PRW in the mandibular teeth than women.

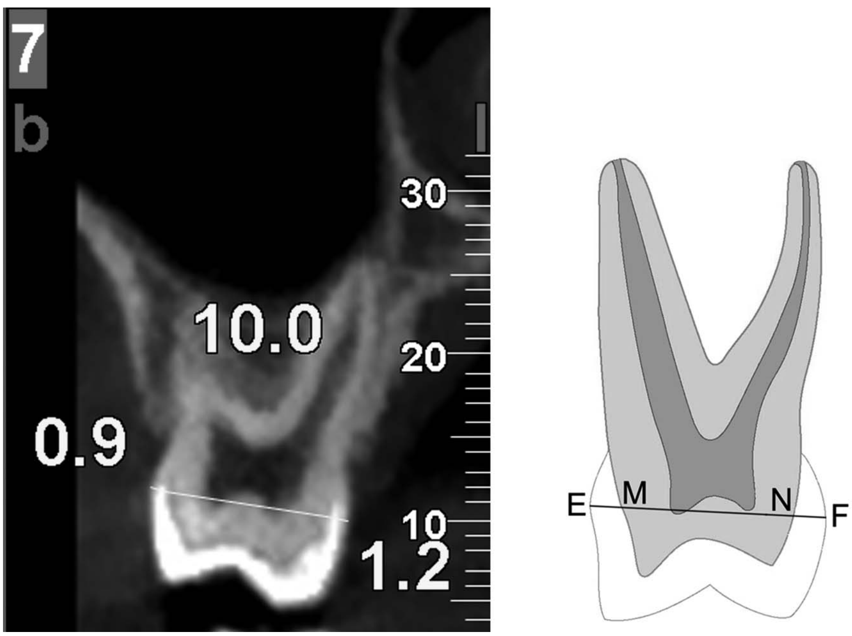

FIGURE 2. Measured variables on the maxillary tooth. EM, palatal enamel at the HOC; NF, buccal enamel thickness at the HOC; MN, dentin thickness at the HOC.

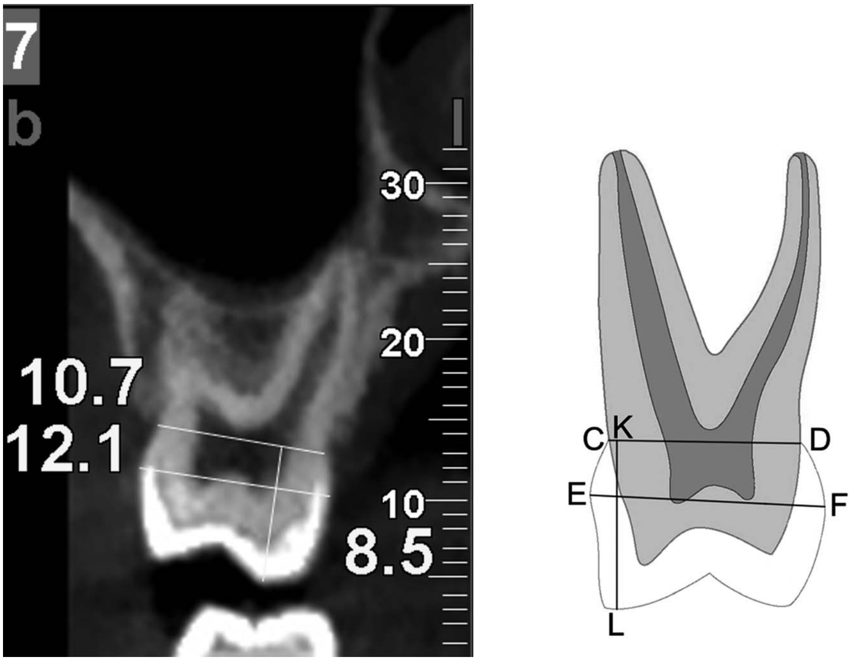

FIGURE 3. Measured variables on the maxillary tooth. EF, tooth width at the HOC; CD, tooth width at the cervix; LK, maximum crown length.

The results of multivariate discriminant analyses are summarized in Table 2 for different teeth in the MD aspect. For the maxillary teeth, the most dominant variable in discriminating the 2 sexes was CH (SCDFC = 0.664), followed by WH, PFW, PRW, and DH. The formula to estimate the sex group could be extracted from the CDFC columns. However, after applying the stepwise selection method, only 2 variables of CH and WH remained in the reduced model. The reduced model to estimate the sex group was $D = -17.87 + 1.01\ (WH) + 1.25\ (CH)$, so that a negative value for D was indicative of a female individual and vice versa. The accuracy rates of the full and reduced models were 78% and 72%, respectively. For the mandibular teeth, PH played the most critical role in discriminating 2 sexes (SCDFC = 0.516), followed by DH, WC, PRW, and WH. By applying the stepwise selection method, it was found that only PH, DH, and PRW measurements were sufficient to differentiate the sex groups adequately. The final formula

TABLE 1. Comparison of Mean Measurements Between the 2 Sex Groups

		MD Surface			BL Surface		
Jaw	**Variable**	**Male**	**Female**	***P***	**Male**	**Female**	***P***
Maxilla	WH	10.35 ± 0.55	9.93 ± 0.43	<0.001	11.33 ± 0.68	10.96 ± 0.57	0.004
	WC	8.04 ± 0.69	7.83 ± 0.62	0.117	10.53 ± 0.87	10.31 ± 0.67	0.147
	PFW	2.46 ± 0.91	1.93 ± 0.52	0.001	5.23 ± 1.02	4.82 ± 0.67	0.022
	PRW	3.15 ± 0.52	2.93 ± 0.37	0.021	4.76 ± 0.67	4.67 ± 0.58	0.331
	DE or BE	1.20 ± 0.22	1.21 ± 0.23	0.757	0.84 ± 0.25	0.89 ± 0.27	0.387
	ME or LE	1.22 ± 0.29	1.23 ± 0.27	0.886	1.00 ± 0.28	1.04 ± 0.24	0.470
	DH	7.84 ± 0.56	7.49 ± 0.37	<0.001	9.36 ± 0.68	8.94 ± 0.74	0.005
	CH	6.43 ± 0.63	5.77 ± 0.59	<0.001	7.18 ± 0.71	6.56 ± 0.77	<0.001
	PH	2.37 ± 0.74	2.26 ± 0.58	0.419	2.35 ± 0.73	1.95 ± 0.88	0.016
Mandible	WH	11.23 ± 0.52	10.87 ± 0.61	0.002	10.62 ± 0.50	10.25 ± 0.82	0.006
	WC	9.19 ± 0.46	8.84 ± 1.06	0.036	9.18 ± 0.66	9.15 ± 0.53	0.789
	PFW	3.86 ± 0.53	3.69 ± 0.50	0.100	3.40 ± 0.82	3.13 ± 0.68	0.078
	PRW	3.92 ± 0.45	4.20 ± 0.55	0.005	3.84 ± 0.42	3.67 ± 0.43	0.039
	DE or BE	1.33 ± 0.29	1.35 ± 0.28	0.756	0.98 ± 0.30	1.02 ± 0.24	0.436
	ME or LE	1.22 ± 0.23	1.24 ± 0.30	0.794	0.88 ± 0.21	0.95 ± 0.24	0.129
	DH	8.61 ± 0.48	8.22 ± 0.61	0.001	8.71 ± 0.52	8.37 ± 0.49	0.001
	CH	6.46 ± 0.74	6.22 ± 0.66	0.090	7.06 ± 0.66	6.77 ± 0.59	0.024
	PH	1.56 ± 0.66	1.37 ± 0.61	0.124	2.21 ± 0.78	2.17 ± 0.67	0.815

DE or BE, distal or buccal enamel thickness at the HOC; ME or LE, mesial or lingual enamel thickness at the HOC.

TABLE 2. The Results of Discriminant Analyses for the Measurements on the MD Aspect of Teeth

Full Model				Reduced Model	
Jaw	**Variables**	**CDFC**	**SCDFC**	**CDFC**	**SCDFC**
Maxilla	WH	0.833	0.414	1.012	0.503
	WC	−0.113	−0.074	—	—
	PFW	0.438	0.324	—	—
	PRW	−0.681	−0.308	—	—
	DE	0.229	0.052	—	—
	ME	−0.404	−0.113	—	—
	DH	0.625	0.297	—	—
	CH	1.086	0.664	1.247	0.762
	PH	−0.023	−0.015		—
	Constant	−17.585	—	−17.869	
Mandible	WH	0.520	0.296	—	—
	WC	0.413	0.339	—	—
	PFW	−0.010	−0.005	—	—
	PRW	0.658	0.330	0.956	0.480
	DE	0.238	0.069	—	—
	ME	−0.721	−0.193	—	—
	DH	0.899	0.496	1.433	0.790
	CH	0.299	0.210	—	—
	PH	0.816	0.516	0.853	0.539
	Constant	−22.191	—	−17.189	—

obtained from the reduced model was −17.19 + 0.96 (PRW) + 1.43 (DH) + 0.85 (PH). The accuracy of the full and reduced models for discriminating the 2 sexes was 74% and 68%, respectively.

Table 3 shows the results of discriminant analyses for the BL surface. For maxillary teeth, the full model revealed that the most prevailing variable in the differentiation of sex groups was WH (SCDFC = 1.060). The other useful variables based on their SCDFCs were DH, CH, and lingual enamel (LE); however, only CH (SCDFC = 1) remained in the reduced model using the stepwise method (formula = −9.27 + V8). The amount of accuracy for the full and reduced models was 69% and 66%, respectively. For the mandibular teeth, the most important discriminators were WC (SCDFC = 0.565) and DH (SCDFC = −0.454). Only DH remained in the reduced model (formula = −16.76 + V7). The accuracy of the full and reduced models was 72% and 64%, respectively.

Although considering all 18 measurements in the MD and BL surfaces improved the classification accuracy rate to 84% for the maxillary and 77% for the mandibular teeth, the stepwise selection method demonstrated that the measurements carried out on the BL surface had no substantial impact on the sex discrimination (Table 4). For the maxillary teeth, CH (SCDFC = 0.762) and WH (SCDFC = 0.503) were the only variables in the final model, whereas no measurements on the buccal surface was remained in the model. The ultimate formula was:

$$D = -17.87 + 1.01\ (WH) + 1.25\ (CH)$$

A negative D score indicated that the participant was female, whereas the positive value estimated the sex of the participant as male. For the mandibular teeth, only the DH from the buccal surface remained in the reduced model. However, among the 4 final variables, no substantial impact was found on the sex differentiation (SCDFC = 0.472) when compared with the 3 measurements from the MD surface. The reduced formula was D = −21.20 + 0.95 (PRW) + DH + 0.71 (PH) + 0.93 (PH (BL)).

DISCUSSION

Dental features in sex identification are generally classified into nonmetrical and metrical methods. A nonmetrical method, based on the presence or absence of a particular morphological feature, involves a significant level of subjectivity. Alternatively, metric features, based on tooth measurements, are more precise and less subjective; furthermore, it can be repeated to validate the obtained results.[17] Radiographs serve as an antemortem and postmortem records for human identification in forensic medicine, especially in cases where the body is burned, decomposed or severely degraded.[16,18] In many instances, the dentition is too fragmented by antemortem (ie, trauma, burning), postmortem (ie, weathering, soil acidity) factors or both to allow for measuring each tooth in either dental arch. However, among the dentition, the first molar teeth are lost less frequently than the anterior teeth which have just a single root.[19] Therefore, in the present study, the first molar teeth were evaluated.

The present study assessed the radiological prediction of sex by linear measurements of the maxillary and mandibular first molars in women and men based on CBCT images.

Univariate Sex Dimorphism

In the present study, marginal enamel thickness was not significant between both sexes in the maximum MD and BL widths. In agreement with our findings, a study performed by Stroud et al[20] concluded that there were no significant sex differences in either mesial or distal enamel thickness. In the present study, men were found to have significantly higher mean values for the DH leading to a greater tooth WH in our findings. This result is in the same line with the studies conducted by Schwartz and Dean[21] and Stroud et al.[22] The differences in the dentin thickness could be associated with the differential effects of the Y chromosome on dentin formation.[23]

TABLE 3. The Results of Discriminant Analyses for the Measurements on BL Aspect of the Teeth

Full Model				Reduced Model	
Jaw	**Variables**	**CDFC**	**SCDFC**	**CDFC**	**SCDFC**
Maxilla	WH	1.689	1.060	—	—
	WC	−0.118	−0.092	—	—
	PFW	0.433	0.374	—	—
	PRW	−0.762	−0.476	—	—
	BE	−0.992	−0.263	—	—
	LE	−1.915	−0.502	—	—
	DH	−0.780	−0.553	—	—
	CH	0.709	0.526	1.349	1.000
	PH	0.534	0.432	—	—
	Constant	−12.259	—	−9.272	—
Mandible	WH	0.423	0.287	—	—
	WC	−0.761	−0.454	—	—
	PFW	0.263	0.198	—	—
	PRW	0.573	0.244	—	—
	BE	−0.008	−0.002	—	—
	LE	−0.870	−0.199	—	—
	DH	1.108	0.565	1.963	1.000
	CH	0.463	0.289	—	—
	PH	0.165	0.120	—	—
	Constant	−12.686	—	−16.762	—

TABLE 4. The Results of Discriminant Analyses for the Measurements on Both MD and BL Aspects of the Teeth

Full Model				**Reduced Model**	
Jaw	**Variable**	**CDFC**	**SCDFC**	**CDFC**	**SCDFC**
Maxilla	WH (MD)	1.041	0.517	1.012	0.503
	WC (MD)	−0.130	−0.086	—	—
	PFW (MD)	0.376	0.279	—	—
	PRW (MD)	−0.605	−0.274	—	—
	DE	0.081	0.018	—	—
	ME	−1.071	−0.299	—	—
	DH (MD)	0.509	0.242	—	—
	CH (MD)	0.685	0.419	1.247	0.762
	PH (MD)	−0.901	−0.599	—	—
	WH (BL)	1.149	0.721	—	—
	WC (BL)	−0.364	−0.284	—	—
	PFW (BL)	0.490	0.423	—	—
	PRW (BL)	−0.485	−0.303	—	—
	BE	−1.658	−0.439	—	—
	LE	−1.095	−0.287	—	—
	DH (BL)	−0.459	−0.325	—	—
	CH (BL)	0.087	0.064	—	—
	PH (BL)	1.030	0.834	—	—
	Constant	−18.542	—	−17.869	—
Mandible	WH (MD)	0.076	0.044	—	—
	WC (MD)	0.475	0.389	—	—
	PFW (MD)	−0.022	−0.011	—	—
	PRW (MD)	0.457	0.229	0.949	0.476
	DE	0.708	0.204	—	—
	ME	−0.435	−0.116	—	—
	DH (MD)	0.930	0.513	0.996	0.549
	CH (MD)	0.052	0.037	—	—
	PH (MD)	0.843	0.533	0.708	0.448
	WH (BL)	0.213	0.145	—	—
	WC (BL)	−0.604	−0.360	—	—
	PFW (BL)	0.408	0.307	—	—
	PRW (BL)	0.065	0.028	—	—
	BE	−0.140	−0.038	—	—
	LE	−0.352	−0.081	—	—
	DH (BL)	0.547	0.279	0.928	0.472
	CH (BL)	0.158	0.098	—	—
	PH (BL)	−0.211	−0.153	—	—
	Constant	−19.818	—	−21.196	—

In the MD aspect, the measured pulpal variables of the maxillary and mandibular first molars showed sexual dimorphism, except for pulpal height, which is consistent with the study conducted by Chandler et al.[6] In contrast, Khojastepour et al[24] reported no significant differences in any pulp chamber dimensions between the sexes. Shaw and Jones[25] also found no significant differences between the width of the pulp chamber of the first molars between boys and girls with an age range of 11 to 14 years.

The crown height of the first molars showed sexual dimorphism. Our result is following those of Banerjee et al's study,[26] who reported longer teeth significantly in men than in women. However, the study conducted by Chandler et al[6] showed that there was sexual dimorphism in only the mandibular teeth. Vodanović et al[1] measured the crown height on the buccal side of the postmortem first molars, and the result was significant. However, women had higher values than men.[1] The cervical crown width of the first molars had no significant role in sexual dimorphism, except for the MD aspect of the mandibular first molar. Zorba et al[27] and Chandler et al[6] revealed significant differences in the diameter of the tooth cervix of the maxillary and mandibular teeth between women and men, whereas no sexual dimorphism was observed in the width of the tooth cervix in the study conducted by Vodanović et al.[1] These controversies among the results may be related to several factors, such as ethnicity and age of the studied individuals.

Multivariate Discriminant Analysis

On the MD aspect of the maxillary first molar, the most potent variables for sex differentiation were CH and WH, whereas for the mandibular teeth, they were PH, DT, and PRW. Although BL variables are sex determinative, MD measurements had greater accuracy (74%–78%) in sex differentiation than BL measurements (69%–72%). Acharya and Mainali[14] in 2008 reported that the MD dimensions had higher accuracy (77.4–83%) in sex identification than BL dimensions (62.3–64.2%), which is consistent with our results. Similarly, Potter[28] and Achyra et al[5] demonstrated that MD variables had greater utility in sex assessment than the BL variables. The stepwise discriminant analyses conducted by İşcan and Kedici[29] only for BL dimensions were indicative of low accuracy for the BL measurements. Banerjee et al[26] reported the MD width of the maxillary first molar was found to be better in establishing sexual dimorphism in comparison to the BL width; this is consistent with our study results. The better sex discriminatory ability of the MD variables could be related to the arch dimensions. The anterioposterior dimension of the jaws is larger in men, which can affect the tooth size in such a way that larger jaws in men result in correspondingly larger MD tooth dimensions. In contrast to our data, some previous studies reported that the BL dimensions are better sex predictors than MD dimensions.[2,7,15,19] This disparity can be due to the differences in the measurement tools and statistical analyses. None of the previous studies performed the multivariate discriminant analysis for BL and MD comparison, which is probably the reason for the discrepancy with our findings. Furthermore, they used cast models for measuring the variables. The existence of the proximal contact between the first molars and adjacent teeth on the cast model at the HOC probably makes these measurements less reliable compared with the BL measurements. Ease in obtaining MD measurements might also be undermined by crowding in the jaws and altered tooth alignment. These limitations can be overcome by using CBCT images with small thickness cross-sections.

Considering all 18 measurements in the MD and BL surfaces, the classification accuracy rate for maxillary and mandibular first molars was 84% and 77%, respectively; it just demonstrated that those who had maxillary measurements were estimated more accurately.

Therefore, the maxillary first molars were found to exhibit more significant sexual dimorphism than the mandibular first molars. Our findings are in agreement with Metgud et al[2] and Achayra and Mainali,[5] and Metgud's studies that reported a higher accuracy rate of assessing sex by the maxillary teeth followed by the mandibular teeth.

Further investigations are required to measure both maxillary and mandibular teeth simultaneously in each patient to compare the accuracy of the maxillary and mandibular first molars for sex discrimination.

CONCLUSION

Our data suggested that the first molar exhibited sexual dimorphism. The maxillary first molar was more dimorphic than the mandibular first molar. The MD measured variables were more accurate in sexual differentiation than BL ones. For sex differentiation, the most dominant variables for the maxillary and mandibular first molar teeth were CH and DT on the MD aspect, respectively.

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