

# Sexual dimorphism in tooth morphometrics: An evaluation of the parameters

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## Introduction

Sexual dimorphism refers to those differences in size, stature and appearance between male and female that can be applied to dental identification because no two mouths are alike.<sup>[1]</sup> Gender determination always plays a pivotal role in solving medico-legal cases as well as in anthropological studies. Sex may be determined from

## Abstract

**Aims and Objectives:** Sexual dimorphism refers to the variations in tooth size and shape between the sexes. The consistency of these variations is valuable in the identification of the sex of an individual in times of mass disaster when whole body parts get destroyed or are unavailable. There exist differences in the expression of these variables across races and regions. This study aims to tabulate and identify the variations in tooth measurements using standardized reference points in an attempt to establish parameters of sexual dimorphism. **Materials and Methods:** 100 individuals (50 of each sex) in the age group 19-23 years were assessed for standard morphometric parameters of the maxillary central incisor, canine, premolar and molar. Odontometric measurements of established parameters were recorded from impression casts of the maxillary jaws. The mesiodistal width (MDW), the bucco-ligual width (BLW), the crown length (CL) and the cervical angle (CA) were charted among the teeth. The consistency of the variations was statistically analyzed and a logistic regression table was prepared to identify the sex of the individual from the tooth measurements. **Results and Conclusions:** The BLW, MDW and CL reflected significant variations among all the teeth to be effective in establishing sexual dimorphism. CA as a parameter was inadequate across all the teeth. The permanent maxillary canine was the most important tooth to be reflective of the gender and statistically significant to be utilized for gender determination.

**Key words:** Gender determination, odontometrics, sexual dimorphism, tooth measurements, tooth morphometrics

various parts of the body like the skull remains, bones etc., Teeth are considered as the strongest structure since they are resistant to mechanical, chemical, physical thermal effects microbial degradation and other post mortem insults. Gender determination using dental features is primarily based upon the comparison of tooth dimensions in males and females, or upon comparing the non-metric dental traits. Morphometrics plays an important role in determining the gender in cases of major catastrophes when the bodies are often damaged beyond recognition. Tooth size standards based on odontometric investigations can be used in age and sex determination as human teeth exhibit sexual dimorphism.<sup>[2]</sup> The importance of odontometrics in gender determination is reflected in various studies carried out on the subject across the globe.<sup>[2-25]</sup> The present study endeavors to evaluate morphometric measurements of the permanent maxillary dentition including central incisor,

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canine, first premolar and the first molar (representative teeth of each series) for sexual dimorphism and to estimate the level of accuracy with which they could be used for gender determination.

## Materials and Methods

The study was carried out in 50 male and 50 female subjects ( $n = 100$ ) in the institution at department of oral and maxillofacial pathology between the age group of 19-23 years, considering attrition is found minimal in this age group.<sup>[18-20]</sup> The study was carried out over a period of 6 months from July 2013 to Dec 2013. The study has the approval of the Institutional Ethics Research Committee. Following informed written consent, impressions of the upper and the lower arches were made using irreversible hydrocolloid (alginate) material and dental stone casts fabricated. Four parameters were taken into consideration for assessing tooth morphometry: Buccolingual width (BLW), mesiodistal width (MDW), clinical crown length (CL) and cervical angulation (CA). All the measurements except for CA were measured with the help of digital vernier calipers (Aerospace Ltd, Bangalore) with a resolution of 0.002 mm; CA was measured using an angle protractor. The parameters and landmarks used for the odontometric exercise are explained below:

- MDW – greatest distance between the contact points on the approximate surfaces of the crown and measured with the caliper beaks placed occlusally along the long axis of the tooth
- BLW – greatest distance between the labial/buccal surface of the crown measured with the caliper held perpendicular to MDW
- CL – a reference plane that is drawn along the long axis of the tooth (central incisor, canine, first premolar) and in case of molar a line from gingival margin to mesiobuccal cusp tip parallel to the groove between the mesiobuccal and distobuccal cusp tip
- CA was measured with a protractor over the traced cervical contour of the teeth on the tracing paper.

The inclusion criteria for the participants in the study were as follows:

- Healthy state of gingiva and periodontium
- Presence of fully erupted permanent maxillary teeth upto the second molars
- Caries free teeth
- Normal overjet and overbite
- Normal molar and canine relationship.

Data obtained from various measurements was recorded on a proforma and sexual dimorphism assessed as per Garn and Lewis formula:<sup>[2]</sup>

$$\{X_m/X_f\}^* - 1 \times 100,$$

Where

$X_m$  – mean of male tooth dimension;

$X_f$  – mean of female tooth dimension.

The observations were further statistically analyzed using stepwise discriminant function statistics (SPSS version 15) and Mann-Whitney U test. Spearman correlation coefficient test was used to test the relation between the dependent variable and predictive variables. Stepwise multi-regression analysis was done to select the most significant predictive variables. In all tests the probability ( $P$ ) was used.

If  $P > 0.05$ , the relation is non-significant.

If  $P < 0.05$ , the relation is significant.

## Results

The morphometric measurements taken from the representative teeth in the maxillary series were analyzed statistically for their viability in the expression of values between the sexes.

### Central incisor

Of the four parameters evaluated in this tooth three expressed statistical significance (MDW, BLW, CL) between the sexes at  $P$  intervals of 0.05. The parameter of CL expressed the most significance in this series [Table 1].

### Canine

In this tooth series all the parameters were statistically significant. The  $P$  intervals were the most significant among the series of all the teeth examined [Table 2].

### First premolar

Surprisingly the maxillary first premolar presented with the most variables in its morphometric measurements. None of the assessed parameters was found to be statistically significant. The existence of variations in the morphometric measurements of this series amongst the sexes thus seems to be statistically unsustainable [Table 3].

### First molar

Three parameters (MDW, BLW, CL) were found to be statistically significant in evaluating sexual dimorphism.

**Table 1: Statistical analysis of the various parameters in the central incisor series**

Parameters	Gender	Central incisor			
		Mean (mm)	Std. dev	Median (mm)	<i>P value*</i>
MDW	Male	8.78	0.61	8.88	0.024
	Female	8.38	1.26	8.45	
BLW	Male	6.97	0.60	6.98	0.026
	Female	6.71	0.49	6.75	
CL	Male	9.99	0.91	9.99	0.001
	Female	9.42	0.86	9.16	
CA	Male	105.09	10.98	90.50	0.912
	Female	89.48	5.62	90	

\*Figures in bold italics indicate statistical significance. MBW: Mesiodistal width, BLW: Bucco-ligual width, CL: Crown length, CA: Cervical angle

The CL parameter again was found to be the most significant in the group. As in the central incisor teeth, the CA parameter seemed unviable amongst the series [Table 4].

A logistic regression establishing an odds ratio at the 95% confidence interval (C.I) among the parameters and the teeth was carried out to analyze the significance of the parameters that could possibly be used to establish sexual dimorphism. This analysis incorporated only the most significant of the parameters previously obtained. The premolar tooth was excluded due to its variability. The CL parameter in the central incisor series was found to be the most viable in its ability to establish sexual dimorphism. In the canine series three parameters were established as being of reasonable significance – MDW, BLW, CL. The MDW parameter was found to be most plausible in establishing sexual dimorphism followed by BLW and CL. In the molar series the MDW parameter was found to be the most reliable [Table 5].

An attempt to statistically correlate the parameters in the different teeth series (comparison of significance of the parameters within themselves as related to the teeth) was made. In the central incisor and canine teeth series the BLW and CL parameters were found to express statistical significance internally when compared with the others. This indicates that in the two teeth, the parameter of MDW showed a proportional increase to BLW measurements and BLW proportionally increased with CL. This co-relation was significant at the C.I of 0.05 (two-tailed). A similar co-relation at the C.I interval of 0.01 (two-tailed) was found among the parameters of BLW in the first premolars and CA in the first molars. The correlation was that in the premolars MDW increases with BLW and in the molars it is MDW which increases with CA. The latter denotes decreased sensitivity and increased variability in the use of this parameter for establishing sexual dimorphism [Table 6].

Following the documentation and statistical evaluation of the variations and their significance of the parameters a receiver operating curve was plotted in an attempt to compute a “cut-off” figure that would most probably indicate the gender of the tooth. [Table 7] presents this data related to all the assessed parameters in the different teeth series. It is to be noted that the table at best attempts to give a range of the predictive values for gender determination and is by no means conclusive.

## Discussion

The observation that there exist variations in tooth size and shape among males and females has been recognized from a long time. The specificity, sustainability and reproducibility of these variations has been a matter of conjecture and subject of numerous studies on sexual dimorphism [Table 8]. The resistance of the teeth to various natural degradatory agents

**Table 2: Statistical analysis of the various parameters in the canine series**

Canine					
Parameters	Gender	Mean	Std. dev	Median	P*
MDW	Male	7.94	0.49	7.93	0.001
	Female	7.64	0.41	7.61	
BLW	Male	7.63	0.63	7.71	0.002
	Female	7.29	0.56	7.35	
CL	Male	9.48	0.82	9.49	0.001
	Female	8.70	0.76	8.70	
CA	Male	87.29	5.28	86.50	0.001
	Female	82.41	7.14	84	

MBW: Mesiodistal width, BLW: Bucco-ligual width, CL: Crown length, CA: Cervical angle

**Table 3: First premolar: Statistical analysis of the various parameters in the first premolar series**

Parameters	Gender	Mean	Std. dev	Median	P
MDW	Male	7.07	0.57	7.16	0.605
	Female	7.04	0.40	7.11	
BLW	Male	8.63	0.71	8.71	0.082
	Female	8.44	0.47	8.47	
CL	Male	27.91	1.45	7.41	0.059
	Female	7.02	0.72	6.95	
CA	Mal	83.96	5.29	84.75	0.059
	Female	84.56	12.34	86.50	

MBW: Mesiodistal width, BLW: Bucco-ligual width, CL: Crown length, CA: Cervical angle

**Table 4: Statistical analysis of the various parameters in the first molar series**

First molar					
Parameters	Gender	Mean	Std. dev	Median	P
MDW	Male	10.31	0.614	10.31	0.004
	Female	10	0.560	9.94	
BLW	Male	10.11	0.676	10.02	0.009
	Female	9.76	0.616	9.67	
CL	Male	5.89	0.580	6.05	0.001
	Female	18.03	0.88	5.62	
CA	Male	97.18	13.55	100.75	0.774
	Female	98.48	6.501	98	

MBW: Mesiodistal width, BLW: Bucco-ligual width, CL: Crown length, CA: Cervical angle

**Table 5: A logistic regression analysis of the most significant parameters in the teeth**

Logistic regression-males					
Teeth	Parameter	P value	Odds ratio	95% C.I	
				Lower	Upper
Molar	MDW	0.032	0.448	0.216	0.932
	BLW	0.022	0.468	0.245	0.895
Canine	MDW	0.012	0.229	0.073	0.772
	BLW	0.001	0.276	0.143	0.533
	CL	0.001	0.872	0.802	0.949
Central incisor	CL	0.003	0.475	0.291	0.777

MBW: Mesiodistal width, BLW: Bucco-ligual width, CL: Crown length

like fire, water, etc., makes them ideal candidates for age and sex determination in times of identification crises.

In identifying the specificity and sensitivity of the parameters in tooth morphometrics there seems to be a general consensus and MDW, BLW, CL seem to be most commonly assessed. CA has hitherto not been employed as parameter in assessment of sexual dimorphism. The curvature of the cervical angle is broadly in conformity with the facial convergences especially at the gonial angles. We thus deliberately attempted to include this parameter in the study. Unfortunately this parameter could not hold up with consistency in comparison with the others. The molar teeth were the only ones in the series to show some significance in the assessment of this parameter.

The sexual dimorphism observed in molars was found to be 3.1% for MDW and 3.5% for BLW. Similar figures have been reported earlier.<sup>[6,7]</sup> Variations have been found in other studies ranging from 1.9%<sup>[4]</sup> and 6%.<sup>[9]</sup> Sample size and selections, racial and genetic differences probably due to the difference in racial origin are the possible reasons for the divergences. This seems substantiated by the concurrence in the results of significant sexual dimorphism existing in the molars in Indian studies.<sup>[8,13,19]</sup>

In premolars the MDW parameter showed no significant results. This observation seems to be generally accepted and previous studies have stressed on the variability of the tooth in expressing significant sexual dimorphism.<sup>[4,8,22]</sup>

The permanent maxillary canine was found to be a better teeth for assessment of gender and this view seems to be reflected in several previous studies.<sup>[3,5,7,8]</sup> The mean BLW of the canine in the males ( $7.63 \pm 0.63$ ) and the females ( $7.29 \pm 0.56$ ) was almost similar to results obtained in previous studies on the tooth.<sup>[4,15]</sup>

BLW of the incisor expressed a significant percentage of sexual dimorphism (3.81%) a feature recorded in previous studies.<sup>[8,22]</sup> Interestingly the mean values of MDW in males and females of the permanent maxillary central incisor in the present study coincided with those recorded in a North Indian population by Khangura *et al.*<sup>[7]</sup> and showed similar sexual dimorphism.

The present study indicates a definite significant sexual dimorphism in the molar, canine and incisor in the expression of the three parameters MDW, BLW, CL. The canine tooth, in addition, also exhibited sexual variation in CA among males and females which was not seen in the other three representative teeth. On using discriminant logistic regression, it was MDW which proved to be a better parameter than BLW for assessment of gender in case of molar and canine. In case of incisor, the CL was the only parameter which was found better in predicting the gender. Spearman's

**Table 6: Correlations between the parameters related to the teeth**

Teeth	Parameter	MDW	BLW	CL	CA
Molar	BLW				0.209*
Premolar	MDW		0.212*		
Canine	MDW		0.348#		
	BLW			0.318#	
C. Incisor	MDW		0.267#		
	BLW			0.273#	

\*Correlation is significant at the 0.05 level (two-tailed), #correlation is significant at the 0.01 level (two-tailed). MBW: Mesiodistal width, BLW: Bucco-ligual width, CL: Crown length, CA: Cervical angle

**Table 7: A receiver operating characteristics curve to attempt predictive analysis in the establishment of sexual dimorphism**

Teeth	Parameter	Positive if greater than equal to (cut off)
Molar	MDW	7.7
	BLW	7.4
	CL	4.4
	CA	82
Premolar	MDW	4.7
	BLW	7.0
	CL	4.4
	CA	67.5
Canine	MDW	5.5
	BLW	5.0
	CL	6.0
	CA	66
Incisor	MDW	7.4
	BLW	5.4
	CL	6.8
	CA	75.5

MBW: Mesiodistal width, BLW: Bucco-ligual width, CL: Crown length, CA: Cervical angle

correlation coefficient test shows that there exist a positive significant correlation of BLW and CA in molar, in premolar there was weak correlation of MDW with that of the BLW. In both canine and incisor, the MDW showed a correlation with BLW, and BLW with CL at a greater significance level compared to other teeth and their parameters.

Maxillary first premolar did not show any significant sexual dimorphism at any level and none of the parameters were found predictive of gender.

Among all the parameters considered it was CA which was found to be of least importance in gender determination except in case of canine.

An attempt has been made by charting a ROC (receiver operating characteristics) to delineate a value that would reflect sexual dimorphism in teeth [Table 7]. It is proposed that this chart would be a handy tool in the hands of a forensic odontologist to predict the gender of an individual based on tooth dimensions.

**Table 8: Comparison of studies on sexual dimorphism**

Year	Authors	Region	Sample size	Teeth	Parameters
1997	Mohammed <i>et al.</i> <sup>[5]</sup>	Saudi Arabia	-	Canines	MDW
2003	Iscan <i>et al.</i> <sup>[9]</sup>	Turkey	100	All teeth except 3 <sup>rd</sup> molars	BLW
2004	Kaushal <i>et al.</i> <sup>[18]</sup>	Patiala, North India	60	Mandibular anteriors	Canine index
2006	Vodanovic <i>et al.</i> <sup>[4]</sup>	Croatia	86	All teeth from skulls	MDW, BLW, robustness
2007	Acharya, Mainali <sup>[8]</sup>	Nepal	123	All teeth except 3 <sup>rd</sup> molars	MDW, BLW
2007	Rai <i>et al.</i> <sup>[13]</sup>	Haryana, North India	102	Maxillary 1 <sup>st</sup> molar	BLW
2008	Agnihotri, Gulati <sup>[20]</sup>	Haryana, North India	100	Maxillary molar and premolar	Premolar and molar indices
2009	Rani <i>et al.</i> <sup>[11]</sup>	Mysore, South India	99	All teeth except 3 <sup>rd</sup> molars	BLW
2009	Omar and Azab <sup>[15]</sup>	Egypt	220	Canines	MDW, BLW, inter-canine distance
2009	Boaz, Gupta <sup>[24]</sup>	South India	100	Canines	MDW, BLW
2011	Khangura <i>et al.</i> <sup>[7]</sup>	Modinagar, North India	100	Maxillary incisors and canines	MDW
2011	Kapila <i>et al.</i> <sup>[12]</sup>	South India	40	Mandibular canines	MDW
2011	Sonika <i>et al.</i> <sup>[19]</sup>	Mullana, North India	200	Maxillary 1 <sup>st</sup> molar	BLW
2011	Ruengdit <i>et al.</i> <sup>[22]</sup>	Thailand	177	All teeth except 3 <sup>rd</sup> molars	MDW, BLW
2012	Parekh <i>et al.</i> <sup>[3]</sup>	Gujarat, North India	368	Maxillary canines	Canine index
2012	Eboh <i>et al.</i> <sup>[6]</sup>	Urhobos, S Nigeria	100	Maxillary 1 <sup>st</sup> molar	MDW, BLW
2012	Narang <sup>[23]</sup>	Punjab, North India	150	1 <sup>st</sup> molar	BLW
2013	Sharma <i>et al.</i> <sup>[25]</sup>	Muradnagar, North India	200	Maxillary molars	MDW, BLW, cusp diameters

MBW: Mesiodistal width, BLW: Bucco-lingual width

The inherent variations in tooth dimensions and the observed racial differences make gender prediction a complex exercise. Attempts to even out the differences using mathematical equations and statistics seem to compound the matter. While it is generally agreed that there exist definite variations in tooth dimensions among the sexes a predictive chart, of great value in forensic odontology, seems to be elusive.

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