

# Sex determination potential of permanent maxillary molar widths and cusp diameters in a North Indian population

Payal Sharma, Tushita Singh, Piush Kumar, Pavan Kumar Chandra and Rakesh Sharma

## ABSTRACT

**Aims:** To assess the sex discrimination potential of permanent maxillary molar crown widths and cusp diameters.

**Materials and Methods:** Measurements were made on plaster casts of 200 individuals of known sex (100 males, 100 females, aged 12-21 years). Eight parameters were measured on the first and second maxillary molars with a digital caliper [buccolingual, mesiodistal, mesiobuccal-distolingual and distobuccal-mesiolingual crown widths and cusp diameters (hypocone, protocone, paracone, and metacone)]. The percentage of sexual dimorphism for each parameter was calculated. Discriminant function analysis was used to determine the accuracy of sex determination for each molar separately and both the molars taken together.

**Results:** The highest sexual dimorphism was shown by protocone in the first molar and hypocone in the second molar. Furthermore, the sex determination accuracy was highest when the first molar was taken alone than when the second molar or the first and second molars were taken together.

**Conclusion:** Based on this study, odontometric measurements of maxillary molars provide low to moderate sex determination accuracy.

**Key words:** Crown widths, cusp diameters, odontometric, sexual dimorphism

## INTRODUCTION

Identifying the sex of skeletal remains is an important step in building the biological profile of unidentified skeletons recovered in forensic contexts, enabling search of missing person files and recovering antemortem records for comparison or establishing identity. This also decreases the number of wanted individuals to a probability of 50%, which can result in a more accurate identification of the person sought since the subsequent methods for age and stature estimation are often gender dependent.<sup>[1]</sup>

The most reliable results are obtained from morphological and metric analyzes of the bony pelvis and skull. Measurements of the long bones, particularly those of the femur and humerus, may also provide highly accurate sex assessments. It is often the case in forensic practice; however, the only available criterion for determining sex is measuring the permanent dentition since the teeth are more resistant to taphonomic

degradation and postmortem insults, better than any other skeletal structures. Teeth are often preserved even when the bony structures of the body are destroyed, because of their physical characteristics and the protection they get from the jaw bones. Teeth, being the hardest and chemically the most stable tissue in the body are an excellent material in living and non-living populations for anthropological, genetic, odontologic, and forensic investigations.<sup>[2]</sup> Gender dimorphism in tooth size has been demonstrated by anthropologists and odontologists in bucco-lingual and mesio-distal dimensions of teeth (linear dimensions),<sup>[3-6]</sup> and diagonal measurements of tooth crowns.<sup>[7,8]</sup> Dental indices have also been employed to determine sex.<sup>[9]</sup>

The crowns of maxillary molars have four main cusps, namely the paracone, protocone, metacone and hypocone [Figure 1]. Each cusp has an independent growth pattern and a different evolutionary background. The paracone is the first to appear

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both ontogenetically and phylogenetically and is regarded as the success or of the single cone of the reptilian haplodont dentition. The hypocone tends to develop last in terms of ontogeny and phylogeny, and it differentiates from the lingual cingulum. Odontometric characteristics of each molar crown are thought to represent a cumulative effect of individual cusp dimensions, so analysis based on measurement of cusp dimensions promises to be more meaningful biologically than conventional measurements of whole crowns.<sup>[10]</sup>

The aim of this study was to assess the sex discrimination potential of permanent maxillary molar crown widths and cusp diameters.

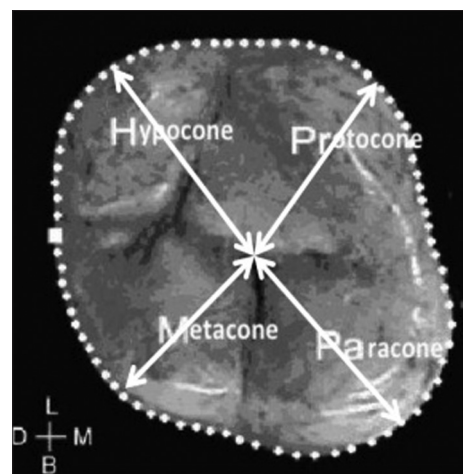
## MATERIALS AND METHODS

The dental material used in this investigation was drawn from the pretreatment records of the department of orthodontics from a postgraduate dental institute. The maxillary plaster casts of 200 subjects of known sex (100 males, 100 females) and of North Indian origin were selected for the study. The age of the subjects ranged from 12-21 years. The selected models had completely erupted and intact first and second permanent molars and were relatively intact and free of pathology and wear, there by maximizing odontometric information. Only molar spossessing all the four principal cusps namely the protocone, paracone, metacone, and hypocone and a clearly distinguishable central pit were used.

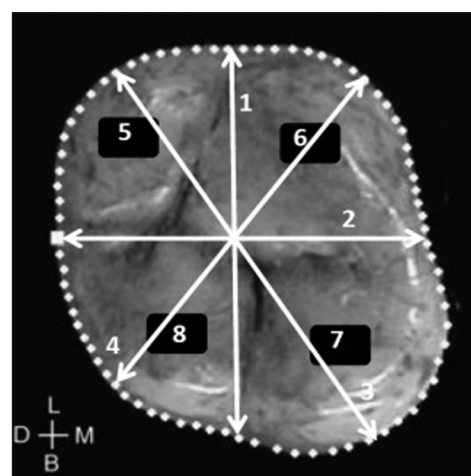
Tooth crowns in which the main fissure separating cusps were obscure, due to either dental restorations or marked occlusal wear, were excluded from the analysis. Any subjects with carious maxillary molars or teeth with unclear crown morphology were excluded.

The mesiodistal (MD), buccolingual (BL), and diagonal mesiobuccal-distolingual (MD-DL) and distobuccal-mesiolingual (DB-ML) crown dimensions of the left permanent maxillary first and second molars were measured on the models using the digital calipers (Mitutoyo, Japan) calibrated to 0.01mm [Figure 2].

The MD dimension was defined as the greatest distance between the contact points on the approximate surfaces of the tooth crown and was measured with the caliper beaks placed occlusally along the long axis of the tooth. The BL measurement was defined as the greatest distance between the labial/buccal surface, and the lingual surface of the tooth crown, measured with the caliper beaks held at right angles to the MD dimension.<sup>[11]</sup> The diameters of all cusps of both molars were also measured. The diameter of the individual cusp was determined by measuring the diagonal distance from the central pit to the most distant point located along the outer margin of the crown corresponding to the relevant cusp. The central pit or fovea located at the bottom of central fossa was defined as the point of intersection of the primary



**Figure 1:** Primary cusps of maxillary first molar



**Figure 2:** Schematic representation of all measurements made: 1. BUCCOLINGUALWIDTH; 2. MESIODISTALWIDTH; 3. MESIOBUCCAL-DISTOLINGUALDIAMETER; 4. MESIOLINGUAL-DISTOBUCCALDIAMETER; 5. HYPOCONE; 6. PROTOCONE; 7. PARACONE; 8. METACONE

occlusal fissures. Although the location of the central pit will be affected by the relative position of cusps, it is a key feature of all maxillary molars that is readily identified on casts and provides an appropriate land mark for assessing the size of individual cusps.<sup>[12]</sup>

All measurements were made by a single observer (P.S.) who was blinded to the sex of the person's cast being measured. Fifty casts were selected randomly and all measurements were repeated by the same observer at an interval of 1 month and by another observer. The intra and inter observer method error were not significant, showing good method reproducibility [Table 1a and b].

## Statistical Analysis

Descriptive statistics (mean and standard deviation) and sexual dimorphism (independent *t*-test) of the crown widths and cusp diameters of maxillary first molar were performed. The percentage of dimorphism is defined as the percent

by which tooth size of males exceeds that of females. The percentage of dimorphism for each tooth was calculated using the formula:<sup>[13]</sup>

$$\text{Percentage of dimorphism} = [(X_m/X_f)-1] \times 100$$

Where  $X_m$  = mean male tooth dimension,  $X_f$  = mean female tooth dimension.

The crown widths and cusp measurement data were subjected to direct discriminant function analyses to develop a set of equations for determining sex. Discriminant function analysis was carried out by taking the gender to be the dependent function of independent variables such as BL, MD, MD-BL, and DB-ML crown widths and all cusp diameters. To address the differential preservation of forensic remains, multivariate functions were generated for both the maxillary first and second molars taken together for more complete remains as well as for each tooth separately, the maxillary first or second molar (M1 or M2) for more fragmentary dentitions.

## RESULTS

The descriptive statistics of crown widths and cusp diameters for both maxillary molars are shown in Tables 2 and 3. Mean values were significantly different between the sexes ( $P < 0.001$ ), with male values exceeding those of females for all measured dimensions.

The percentages of sexual dimorphism revealed that among the cusp diameters, the protocone and paracone displayed the greatest dimorphism in the first maxillary molar, whereas the hypocone and the MB-DL crown width showed the greatest dimorphism in the second maxillary molar.

On collective classification (M1 + M2,  $n=400$ ), all variables showed a significant difference between males and females on assessment of equality of group means. The equation derived using discriminant analysis was as follows:

$$Y = [(0.677 \times \text{BL}) - (0.116 \times \text{MD}) + (0.662 \times \text{MB-DL}) + (0.236 \times \text{ML-DB}) + (0.882 \times \text{Paracone}) - (0.344 \times \text{Hypocone}) + (0.211 \times \text{Protocone}) - (0.684 \times \text{Metacone}) - 16.634]$$

The classified value of Y was found to be  $> -0.003$  for males and  $< -0.003$  for females. On validation, the accuracy of sex assessment was observed to be 64% for males and 62% for females. Overall accuracy was found to be 63% [Table 4].

Ontaking M1 as the classifier ( $n=200$ ), all the variables were found to be significantly associated with discriminant function gender on assessment of equality of group means, except for hypocone and metacone. Hence, they were excluded from the final discriminant function analysis. For the remaining variables, the equation generated was as follows:

**Table 1a: Method error: Intra-observer**

Parameters	n	Mean±SD	Standard error of mean	P
Pair 1				
BL	25	10.98±0.603	0.121	0.327
BL (2)	25	11.00±0.612	0.122	
Pair 2				
MD	25	11.02±0.444	0.0889	1.000
MD (2)	25	11.02±0.489	0.0978	
Pair 3				
MB-DL	25	12.96±0.498	0.100	0.056
MB-DL (2)	25	12.84±0.494	0.0988	
Pair 4				
MD-BL	25	11.34±0.552	0.1108	0.103
ML-DB (2)	25	11.26±0.561	0.1122	
Pair 5				
Hypocone	25	6.96±0.4062	0.0812	0.491
Hypocone (2)	25	6.92±0.4491	0.0898	
Pair 6				
Protocone	25	5.76±0.4592	0.0918	0.161
Protocone (2)	25	5.72±0.502	0.100	
Pair 7				
Paracone	25	5.76±0.3851	0.0770	0.057
Paracone (2)	25	5.66±0.4262	0.0852	
Pair 8				
Metacone	25	5.34±0.3136	0.0627	0.327
Metacone (2)	25	5.32±0.3189	0.0638	

MD – Mesiodistal; BL – Buccolingual; MB-DL – Mesiobuccal-distolingual width; ML-DB – Mesiolingual-distobuccal width

**Table 1b: Method error: Inter-observer**

Parameters	n	Mean±SD	Standard error of mean	P
Pair 1				
BL	25	10.98±0.603	0.121	0.574
BL (2)	25	11.00±0.595	0.1190	
Pair 2				
MD	25	11.02±0.444	0.0889	1.000
MD (2)	25	11.02±0.420	0.0841	
Pair 3				
MB-DL	25	12.96±0.498	0.100	0.185
MB-DL (2)	25	12.90±0.520	0.104	
Pair 4				
MD-BL	25	11.34±0.553	0.1108	0.327
ML-DB (2)	25	11.28±0.501	0.1003	
Pair 5				
Hypocone	25	6.96±0.406	0.0812	0.022
Hypocone (2)	25	7.06±0.363	0.073	
Pair 6				
Protocone	25	5.76±0.459	0.0918	1.000
Protocone (2)	25	5.76±0.481	0.096	
Pair 7				
Paracone	25	5.76±0.385	0.0770	0.664
Paracone (2)	25	5.74±0.411	0.0823	
Pair 8				
Metacone	25	5.34±0.313	0.0627	0.103
Metacone (2)	25	5.42±0.312	0.0624	

MD – Mesiodistal; BL – Buccolingual; MB-DL – Mesiobuccal-distolingual width; ML-DB – Mesiolingual-distobuccal width

$$Y = [(0.254 \times BL) + (0.627 \times MD) + (0.230 \times MBDL) + (0.620 \times MLDB) + (0.003 \times Protocone) + (0.638 \times Paracone) - 22.460]$$

The classified value of Y was found to be >0 for males, whereas the same for females was found to be <0. On validation, the accuracy of the assessment was found to be 69% for males and 64% for females. Overall accuracy was 66.5%.

On taking M2 as the classifier ( $n=200$ ), all variables were found to be significantly associated with discriminant function gender on assessment of equality of group means, except for protocone and metacone. Hence, they were excluded from the final discriminant function analysis. For the remaining variables, the equation generated was as follows:

$$Y = [(0.890 \times BL) - (0.441 \times MD) + (0.707 \times MB-DL) - (0.130 \times ML-DB) + (0.341 \times Paracone) + (0.256 \times Hypocone) - 14.997]$$

The classified value of Y was found to be >0 for males and <-0 for females. On validation, the accuracy of the assessment

was found to be 66% for males and 61% for females. Overall accuracy was 63.5%.

Thus, the first molar showed the maximum accuracy for both genders independently (69% for males and 64% for females) as well as for over all assessment (66.5%).

## DISCUSSION

In many instances, the dentition is too fragmented by perimortem (e.g., trauma, burning) and/or post mortem (e.g., weathering, soil acidity) factors to allow for measuring each tooth in either dental arcade. Like wise, the anterior teeth may not be available for examination. We employed dimensions of the multi-rooted maxillary molars as these teeth are less frequently lost post mortem than the anterior teeth, which possess only a single root. Further more, various antemortem and taphonomic processes can differentially affect the dentition; thus rendering conventional mesio-distal and bucco-lingual crown dimensions useless, yet allowing individual cusp diameters to be measured.

**Table 2: Descriptive statistics and sexual dimorphism of crown widths and cusp diameters of maxillary first molar (M1)**

M-1	Males (n=100) Mean (mm)±SD	Females (n=100) Mean (mm)±SD	P	Sexual dimorphism %
BL	10.7±0.6	10.33±0.67	0.00	3.58
MD	10.89±0.53	10.55±0.57	0.00	3.22
MB-DL	12.69±0.66	12.29±0.64	0.00	3.25
ML-DB	11.06±0.66	10.67±0.57	0.00	3.65
Hypocone	6.91±0.51	6.81±0.48	0.154	1.46
Protocone	5.67±0.54	5.42±0.49	0.001	4.61
Paracone	5.75±0.42	5.51±0.42	0.00	4.35
Metacone	5.28±0.34	5.17±0.41	0.054	2.12

MD – Mesiodistal; BL – Buccolingual; MB-DL – Mesiobuccal-distolingual width; ML-DB – Mesiolingual-distobuccal width

**Table 3: Descriptive statistics and sexual dimorphism of crown widths and cusp diameters of maxillary second molar (M2)**

M-2	Males (n=100) Mean (mm)±SD	Females (n=100) Mean (mm)±SD	P	Sexual dimorphism %
BL	10.47±0.63	10.15±0.68	0.001	3.15
MD	9.63±0.66	9.44±0.66	0.048	2.01
MB-DL	11.58±0.89	11.09±0.84	0.001	4.41
ML-DB	10.06±0.74	9.87±0.71	0.065	1.19
Hypocone	5.76±0.78	5.48±0.7	0.008	5.10
Protocone	5.18±0.58	5.03±0.5	0.053	2.98
Paracone	5.54±0.45	5.39±0.45	0.023	2.78
Metacone	4.81±0.46	4.71±0.43	0.115	2.12

MD – Mesiodistal; BL – Buccolingual; MB-DL – Mesiobuccal-distolingual width; ML-DB – Mesiolingual-distobuccal width

**Table 4: Discriminant function analysis and sex determination accuracy of the first and second molars**

Condition	Generated equation	Accuracy for males %	Accuracy for females %	Overall accuracy %
M-1 or M-2 (N=400)	0.677*BL-0.116*MD+0.662*MB-DL+0.236*ML-DB+0.882*paracone-0.344*hypocone+0.211*protocone-0.684*metacone-16.634	64	62	63
M-1 (N=200)	0.254*BL+0.627*MD+0.230*MBDL+0.620*MLDB+0.003*protocone+0.638*paracone-22.460	69	64	66.5
M-2 (N=200)	0.890*BL-0.441*MD+0.707*MB-DL-0.130*ML-DB+0.341*paracone+0.256*hypocone-14.997	66	61	63.5

MD – Mesiodistal; BL – Buccolingual; MB-DL – Mesiobuccal-distolingual width; ML-DB – Mesiolingual-distobuccal width

For example, a particular postmortem insult may fracture the enamel along the buccal aspect of a molar crown, given its greater exposure to the external environment while leaving the lingual portion of the tooth unaffected. Therefore, the cusp dimensions were also measured as they may be used with even partial tooth crowns.

Various methods to measure crown and cusp dimensions have been used previously. Macaluso<sup>[1]</sup> measured cusp diameters from standardized occlusal view photographs obtained for individual teeth using a digital camera. Direct intra oral measurements were taken with a digital vernier caliper, with the subject sitting in the dental chair by Eboh *et al.*<sup>[9]</sup> and Sonika *et al.*<sup>[13]</sup> In the present study, measurements were made on stone casts from orthodontic records of patients. Dental casts are an accurate reproduction of an individual's teeth in 1:1 ratio and hence can be used to make tooth measurements.

The dimensions obtained for the male teeth were larger compared to those for females; thus exhibiting sexual dimorphism. The male teeth are usually larger in size as compared to the female teeth.<sup>[14,15]</sup> The sexual dimorphism in tooth morphology is attributable to the presence of relatively more dentine in the crowns of male teeth where as the X chromosome seems to be responsible for modulating thickness of the enamel.<sup>[16]</sup> The sexual dimorphism in tooth morphology is attributable to the presence of relatively more dentine in the crowns of male teeth.<sup>[4,16]</sup>

In our study, the bucco-lingual dimensions of maxillary first and second molars exhibited greater sexual dimorphism than mesio-distal dimensions of the same teeth. This result is in agreement with the findings of Garn *et al.*<sup>[17]</sup> who also found greater sexual dimorphism for the BL diameter (5.6%) as compared to the MD diameter (4.2%) of the same teeth in white adolescents.

The cusp size in decreasing order was found to be hypocone > paracone > protocone > metacone in both maxillary first and second molars. This order has been found to differ among populations. In a study conducted by Agnihotri and Sikri<sup>[15]</sup> on Jat Sikhs, the order in cusp size was found to be hypocone > protocone > paracone > metacone. For the Japanese, Kondo *et al.*<sup>[12]</sup> found the sequence to be: protocone > hypocone > paracone > metacone. For American whites, Biggerstaff<sup>[18]</sup> reported the order to be protocone > metacone > paracone > hypocone. This can be attributed to racial differences in the populations studied.

In the first molar, sexual dimorphism was significant in protocone and paracone and not significant in the hypocone and metacone. In the second molar, it was significant in hypocone and paracone and not significant in protocone and metacone. The highest sexual dimorphism was found to be in protocone in the first molar and in hypocone in the second molar. The sexual dimorphism in the cusp dimensions in the first molar was

in the order of protocone > paracone > metacone > hypocone, which again differed from the study on Indian Jat Sikhs in which the order was hypocone > metacone > protocone > paracone. The sexual dimorphism in the cusp dimensions in the maxillary second molar corresponded to hypocone > protocone > paracone > metacone.

The results of the current study are generally consistent with previous investigations concerning sex dimorphism of the maxillary molar cusp diameters in a South African population and in modern Japanese.<sup>[12]</sup> In the current study and in both previously mentioned studies, the greatest percentage of sexual dimorphism was observed in hypocone diameter of the second molar. In addition, hypocone diameter was the second most dimorphic cusp dimension of the first molar crown in Japanese and black South Africans, which was not the case in this study. (revise) There are notable differences between the South African and the Japanese study and the results of the current investigation. In our study, the protocone displayed the highest percentage of sexual dimorphism among all first molar dimensions, which is in accordance with the South African study, but in contrast with the Japanese study where protocone displayed the least dimorphism. Furthermore, metacone diameter was the least dimorphic cusp for both the first and second molar in black South Africans, which was not the case in Japanese dentitions. In the current study, the least dimorphic cusp was hypocone in the first molar and metacone in the second molar. The apparent difference in the pattern of sexual dimorphism between these three geographically disparate populations is likely due to a combination of environmental and genetic factors, given that dental sexual dimorphism is strongly influenced by sex-linked genes.

Maxillary first and second molars provided low to moderate sex discrimination, with overall classification accuracies for the derived discriminant functions ranging between 63% and 66.5%. These classification results are comparable to those reported in a prior study concerning sex allocation in black South Africans based on odontometric data. Specifically, Kieser and Groeneveld<sup>[19]</sup> achieved sex identification rates of 70.2% for males and 66.7% for females utilizing crown length and breadth diameters of the maxillary tooth row. In their study, the highest accuracy was obtained when the first molar was used independently than the second molar or using both the molars together. This is also true for our study where the most accuracy was achieved when the first molar was used independently (66.5%) than when using the second molar (63.5%) or using both first and second molars together (63%).

Orthodontists can play an important role in the post-mortem profiling of forensic remains, which includes identifying the sex and age, when other means of identification are not feasible because of fragmented remains. The equations mentioned in this study, which were generated using patient records taken routinely prior to orthodontic treatment, can contribute to narrowing the search for ante-mortem records by helping

to identify the sex of individuals belonging to the North Indian population.

However, in view of the metric variation that exists between human populations, caution is warranted when attempting to apply the results of this study to an individual from a different population.

## CONCLUSIONS

1. Both the maxillary first and second molars exhibited sexual dimorphism, with male dimensions being larger than females
2. The protocone in the first molar and hypocone in the second molar showed the highest sexual dimorphism
3. Odontometric measurements of maxillary molars provide low to moderate sex discrimination accuracy.

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