Original Article

Cusp Number Traits and the Dental Crown Metric Traits of Mandibular Premolars and Maxillary Second Molar in Sex Determination: A Cross-Sectional Dental Model-Based Observational Study

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ABSTRACT

Background: The size of the posterior tooth crown is defined by the number and size of the cusps and the dimensions in both the mesiodistal and buccolingual planes.
Aim and Objective: The present study was designed to explore the variations in such parameters between genders.
Material and Methods: The dental models of 151 young individuals in the age range of 17–21 years were randomly selected. The crown and cusp dimensions and the number of cusps in mandibular first and second premolars and in maxillary second molars on both the sides were recorded.
Results: The mandibular first premolars showed 97.35% symmetry in the number of cusps between antemers followed by maxillary second molar (88.1%) and mandibular second premolar (82.78%). The mesiodistal and the buccolingual dimensions of the crown in all the three teeth showed significant gender difference. In the maxillary second molar, only the mesiobuccal cusp in the left side showed significant gender difference. In the three cusped second molars, the lingual cusp dimensions showed significant gender difference. The discriminant model using the BL and MD dimensions of all the three teeth showed a canonical correlation of 0.722 (Wilks' lambda = 0.479, $P < 0.001$) with a hit ratio of 90.1%. The classification results showed that 84.1% of the males and 95.1% of females were correctly predicted using this model. The cusp number traits can significantly differentiate genders with a discriminating power of 61%.
Conclusion: The metric data, especially the mesiodistal and the buccolingual dimensions from mandibular premolars and maxillary second molars, can better differentiate gender than the cusp number traits.

Key Words: *Cusp patterning, dental anthropology, discriminant function analysis, mandibular premolars, maxillary second molar, sexual dimorphism*

Introduction

In forensic human identification of unknown remains, especially the skeletal remains, the anthropometric parameters play an important role. However, in cases where the skeletal components do not contribute any data, the role of teeth is considered as they are resistant to both the biological and nonbiological taphonomic factors. The human dentition is of significant anthropological interest when considering variation within and between modern populations.[1] The human dentition demonstrates significant variation in development, form, size, and function. Such variation exists within and between individuals, families, sexes, ethnic groups, and populations. Thus, the form of the tooth can provide opportunities for narrowing down identification process under forensic contexts. The study on the role of genetic, epigenetic, and environmental influences on dental variation has been studied by comparing the tooth size, shape, and cusp forms within and between populations.[2-4] Sex determination is an integral and foremost step for developing a reliable biologic profile during examination of skeletal remains. The sexual dimorphism in teeth is evident in the tooth crown size, especially in the mesiodistal and buccolingual dimensions.[5,6] These two measurements provide significant information on the field of human biological problems such as physical anthropology, oral biology, and orthodontics.[7] The teeth especially the canines and first molars have greater

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dimensional dimorphism in the mesiodistal and buccolingual measurements.[8,9] Some studies have proved canines to be the most dimorphic tooth in the human dentition.[10-12] In human dentition, the mandibular premolars and the maxillary second molars exhibit variation in number of cusps and that usually are reflected on the crown dimensions. Number of cusp variation have also shown symmetrical pattern between antimeres in majority of cases. To the best of our knowledge, sexual dimorphism in mandibular premolars and maxillary second molar was less explored using odontometric parameters. Hence, the present study was designed to explore the odontometric variations of mandibular premolar and maxillary second molar among genders.

Subjects and Methods

One hundred and fifty-one dental stone models of upper and lower arches from the archives of an earlier *in vitro*, odontometric study done by the same principal investigator were selected for the present study. The approval from the Institutional Ethical committee has been obtained for that study (GDCH-IEC-01/2013). The dental models belonged to the undergraduate dental students of Government Dental College and Hospital, Ahmedabad. The research methodologies and the potential use of their dental models were explained to the participants, and written consent was obtained from them before taking the alginate impressions. The following inclusion criteria were followed:

1. All participants aged 17–21 years
2. Wellaligned mandibular dentition without any spacing or crowding in the premolar area
3. Presence of maxillary second molar on either side with clear and full anatomic details of the crown
4. Participants who had not undergone any restorative treatments, especially in the teeth under study.

The maximum buccolingual (BL) and the mesiodistal (MD) dimensions of the mandibular premolars and the maxillary second molar teeth were recorded, following the definitions of Moorrees *et al*.[13,14] Anatomically, the MD dimension is the length of the tooth, and BL dimension is the breadth. The measurements were made by a calibrated examiner, using a digital calliper (Mitutoyo®, Digimatic, Mitutoyo Corp., Japan) accurate to 0.01 mm. The tabulation of the data and its descriptive statistics were done in Office Excel® 2007 (Microsoft®, Redmond, Washington, USA). To assess the reliability of the measurements, a set of twenty dental models from the original set was randomly selected and all the parameters re-measured by the same observer. The difference in the values between the first and second measurements was tested using paired *t*-test and also by using Dahlberg's statistics. It is defined $D=\sqrt{\sum_{1\text{-}1}^{N}\frac{d_I^2}{2N}}$ as where *d*i is the difference between the two measured values and *N* is the sample size.[15]

Statistical analysis

The data were tabulated in Excel sheet and the SPSS software (SPSS for Windows, Version 16.0. SPSS Inc., Chicago, IL, USA) was used for analysis. The normality of data for each variable was checked using Shapiro–Wilk test. The independent samples *t*test was applied to examine the difference in each variable's measurements between genders. Pearson's correlation coefficient and the Mann–Whitney nonparametric test were done to compare the cusp number in antemeres on either side. The discriminant function analysis was performed to test the predictability of the sexes using the MD and BL dimensions variables of all the three teeth under consideration. All tests were carried out with 5% level of significance.

Results

One hundred and fifty-one pairs of dental models belonging to 67 males and 82 females were analyzed. The normality test revealed the measured data to be normally distributed. The paired *t*-test and the application of the Dahlberg statistics revealed an insignificant difference in the measured data of the test samples between both the observers. The right–left correlations with regard to the number of cusps in mandibular first premolar, mandibular second premolars, and in maxillary second molar were significant with *r* value ranging from 0.58 to 0.87 [Tables 1 and 2]. In the first premolar, the two cusp types were more prevalent than the 3 cusp type. Whereas in the second premolar, the 3 cusp type was more prevalent. The mandibular first premolar showed the highest distribution of symmetrical pattern in number of cusps (97.3%) when compared to the mandibular second premolar (82.8%). Majority of the maxillary second molar showed the 4 cusp type. The symmetry in the distribution of the number of cusps in maxillary second molar was observed in 88.08% of the cases [Table 3]. Significant difference in the BL and MD dimensions was observed between right and left mandibular first premolars. Whereas in the mandibular second premolars, the difference was not significant. The lingual cusp dimension in the two cusped first and second premolars was significantly differing between sides [Table 4]. In the 4 cusped maxillary second molar, the dimensions of the DL cusp were significantly different between the sides and not in the ML cusp. In the three cusped type (loss of hypocone), the lingual cusp dimension was not significantly different between the sides [Table 5]. Significant gender difference was observed in BL and MD dimensions of all the teeth under considerations in this study [Table 6]. In the first premolars, the DL cusp dimension on both the sides was not significantly different among genders. The BC dimension in both the first and second premolars on both sides shows significant gender difference. Significant gender difference was observed in the cusp number trait in all the teeth under study except the right maxillary second molar [Table 7]. The discriminant function analysis was performed with gender group as dependent variable and the MD and BL dimensions of all the three teeth on both sides as the independent variables. The test of function revealed a canonical correlation of 0.722 and a significant relationship between the discriminant functions and the grouping variables. The BL dimensions in the mandibular first premolar have more power in discriminating sex than the other variables. The MD dimension of the left mandibular first premolar had the least discriminating power. The classification results

Table 1: The results of cross-tabulation of the number of cusps between right and left mandibular first premolars

#44	#34, frequency (%)			Correlation coefficient (*r*)	Pearson χ^2	Significant*
	2 cusp type	3 cusp type	Total			
2 cusp	133 (88.1)	0	133 (88.1)	0.87	114.01	0.000
3 cusp	4 (2.6)	14 (9.3)	18 (11.9)			
Total	137 (90.7)	14 (9.3)	151 (100.0)			

*Significant at *P*<0.05

Table 2: The results of cross-tabulation of the number of cusps between right and left mandibular second premolars

#45	#35, frequency (%)			Correlation coefficient (*r*)	Pearson χ^2	Significant*
	2 cusp type	3 cusp type	Total			
2 cusp	41 (27.2)	11 (7.3)	52 (34.4)	0.63	59.28	0.000
3 cusp	15 (9.9)	84 (55.6)	99 (65.6)			
Total	56 (37.1)	95 (62.9)	151 (100.0)			

*Significant at *P*<0.05

Table 3: The results of cross-tabulation of the number of cusps between right and left maxillary second molars

#17	#27, frequency (%)			Correlation coefficient (*r*)	Pearson χ^2	Significant*
	3 cusp type	4 cusp type	Total			
3 cusp	16 (10.6)	12 (7.9)	28 (18.5)	0.58	50.05	0.000
4 cusp	6 (4.0)	117 (77.5)	123 (81.5)			
Total	22 (14.6)	129 (85.4)	151 (100.0)			

*Significant at *P*<0.05

Table 4: The descriptive statistics of the dimensions of the crown and cusps in mandibular premolars

Dimensions	Mandibular first premolar						Mandibular second premolar					
	Right		Left		*n*	Significant*	Left		Right		*n*	Significant*
	Mean	SD	Mean	SD			Mean	SD	Mean	SD		
BL	7.76	0.54	7.83	0.57	151	0.001	8.29	0.58	8.34	0.58	151	0.142
MD	6.49	0.43	6.57	0.48	151	0.003	6.47	0.49	6.48	0.47	151	0.755
BC	4.6	0.51	4.83	0.51	151	0.000	4.59	0.57	4.85	0.47	151	0.000
LC	1.5	0.3	1.33	0.35	133	0.000	2.22	0.48	2.08	0.43	41	0.000
MLC	1.95	0.49	1.7	0.43	14	0.129	2.93	0.62	2.65	0.47	84	0.000
DLC	1.55	0.31	1.66	0.19	14	0.348	2.01	0.42	1.93	0.47	84	0.097

*Significant at *P*<0.05. BL: Buccolingual, MD: Mesiodistal, BC: Buccal cusp, LC: Lingual cusp, MLC: Mesiolingual cusp, DLC: Distolingual cusp, SD: Standard deviation

Table 5: The descriptive statistics of the dimensions of the crown and cusps in maxillary second molars

Dimensions	Right		Left		*n*	Significant*
	Mean	SD	Mean	SD		
BL	11.2	0.96	11.08	0.69	151	0.031
MD	8.91	0.66	8.5	0.78	151	0.000
MBC	5.01	0.4	5.06	0.41	151	0.110
DBC	4.32	0.42	4.16	0.54	151	0.000
MLC	5.05	0.5	5.7	0.65	117	0.212
DLC	2.69	0.62	2.32	0.76	117	0.000
LC	5.77	0.64	5.56	0.36	16	0.062

*Significant at *P*<0.05. BL: Buccolingual, MD: Mesiodistal, LC: Lingual cusp, MLC: Mesiolingual cusp, DLC: Distolingual cusp, MBC: Mesiobuccal cusp, DBC: Distobuccal cusp, SD: Standard deviation

revealed that 84% of the males and 95% of the females were correctly predicted using this model and 90.1% of the overall grouped cases were correctly classified using the discriminant function model [Table 8]. The Wilks' lambda revealed a significant relationship between the discriminant functions and the grouping variables.(Wilks' lambda 0.479, P < 0.05). The cusp number trait in the left second molar was more powerful followed by the same trait in the left first premolar and the left second premolar [Table 9]. It was also observed the metric traits, especially the BL and the MD dimensions had better discriminating powers than the cusp number traits in this study. The overall discriminating power of the cusp number traits was only 61%.

Discussion

The dental anthropological data are utilized in routine cases involving forensic human identification. The dental data may supplement the other anthropological data or sometimes may be the only data available for the identification. The sex determination which narrows down the identification process

Table 6: The results of the descriptive statistics of the dimensions of mandibular premolars in male and female subjects

Tooth number	Dimensions	Male		Female		Significant*
		Mean	SD	Mean	SD	
#44	BL	8.14	0.47	7.44	0.37	0.000
	MD	6.64	0.41	6.36	0.40	0.000
	BC	4.78	0.46	4.45	0.50	0.000
	LC	1.57	0.36	1.45	0.25	0.044
	MLC	1.84	0.47	2.25	0.49	0.154
	DLC	1.53	0.26	1.59	0.46	0.805
#34	BL	8.23	0.49	7.49	0.39	0.000
	MD	6.71	0.54	6.44	0.38	0.001
	BC	5.13	0.48	4.58	0.39	0.000
	LC	1.38	0.38	1.30	0.32	0.228
	MLC	1.56	0.37	2.20	0.01	0.000
	DLC	1.65	0.19	1.70	0.23	0.727
#45	BL	8.61	0.53	8.03	0.47	0.000
	MD	6.69	0.50	6.29	0.39	0.000
	BC	4.84	0.60	4.37	0.46	0.000
	LC	2.35	0.55	2.34	0.52	0.957
	MLC	3.05	0.68	2.71	0.44	0.003
	DLC	2.07	0.41	1.93	0.41	0.084
#35	BL	8.66	0.53	8.06	0.46	0.000
	MD	6.72	0.45	6.28	0.38	0.000
	BC	5.08	0.39	4.66	0.44	0.000
	LC	2.05	0.21	2.08	0.45	0.685
	MLC	2.67	0.42	2.63	0.48	0.639
	DLC	2.00	0.45	1.81	0.42	0.033
#17	BL	11.68	1.07	10.80	0.63	0.000
	MD	9.13	0.69	8.73	0.60	0.000
	MBC	5.08	0.42	4.96	0.39	0.059
	DBC	4.34	0.44	4.30	0.40	0.550
	MLC	5.21	0.49	4.87	0.47	0.000
	DLC	2.90	0.66	2.46	0.53	0.000
	LC	6.12	0.57	5.40	0.34	0.003
#27	BL	11.40	0.66	10.82	0.61	0.000
	MD	8.76	0.71	8.28	0.73	0.000
	MBC	5.15	0.42	4.99	0.39	0.018
	DBC	4.24	0.48	4.09	0.57	0.078
	MLC	5.46	0.37	4.92	0.63	0.637
	DLC	2.61	0.78	2.06	0.72	0.000
	LC	5.94	0.35	5.48	0.30	0.000

*Significant at $P<0.05$. BL: Buccolingual, MD: Mesiodistal, LC: Lingual cusp, MLC: Mesiolingual cusp, DLC: Distolingual cusp, MBC: Mesiobuccal cusp, DBC: Distobuccal cusp, BC: Buccal cusp, SD: Standard deviation

to almost 50% forms one of the core domains in forensic odontology. The dental dimensions and some nonmetric traits have contributed as cofactors in sex determination. The studies related to sex determination from teeth focused on both the metric and nonmetric parameters. Studies have proved that sexual dimorphism occurs in both the buccolingual and mesiodistal dimensions.[16,17] The conventional method of odontometric studies uses the handheld vernier calipers. However, revised methods using the 2D photogrammetry and 3D imaging of the dental models were also applied in odontometric studies.[18-20] The present study measured the length and breadth of the crown and the dimension of the cusps using the conventional method. Earlier method used the central pit as one of the references point to measure cusp diameter.[21] In the present study, the investigators modified the method of measuring the cusp diameter. In the maxillary second molar, the MB, ML, and DB cusps were measured diagonally from the central pit to the maximum convexity, while the DL (hypocone) cusp was measured from the distal pit to the maximum convexity of the cusp. The odontometric studies have applied both the discriminant functions analysis and the logistic regression analysis to determine the sex from tooth.[22-24] It was also observed that the LRA application for sex determination is much superior to the DFA.[23] The diagonal tooth measurements were also applied to study the gender differences in teeth. Studies have shown classification accuracy of nearly 47%–80% using the diagonal dimension models.[25,26] In the present study, the mesiodistal and the buccolingual dimensions of the crown were applied to discriminant function analysis for sex determination. The cusp area was also used as a parameter for sex prediction. An earlier study utilized the photogrammetry methods to measure the cusp area and revealed an overall sex prediction accuracy rate between 59.6 and 74.5%.[27] According to Sharma *et al*., the highest degree of sexual dimorphism was observed in the hypocone cusp in the maxillary second molar and the hypocone in the maxillary first molar provided the least degree of sexual dimorphism. In the present study, the BL and the MD dimensions of the mandibular premolars and the maxillary second molar were significantly different among genders. In the two cusped mandibular second premolars, the LC was not showing gender difference in the dimensions. However, in the three cusped maxillary second molars, the LC was showing significant gender difference in the dimensions. Unlike the other studies, the present study also compared the expression of the cusp number traits between genders. The mandibular premolars, especially the second premolar and the maxillary second molars, commonly show variations in the number of cusps. More than 90% of the females had the 2 cusp type of mandibular first premolar and around 75% of the males had 3 cusped second premolars. The frequency of 2 cusp type and 3 cusp type premolars was 37.5% and 62.4%, respectively, according to a study by Ahmed *et al*.[28] Another study from the same population revealed a contradictory result.[29] The distribution of 2 cusp type and 3 cusp types mandibular second premolars was 61.5% and 38.5%, respectively. Similarly, two studies from Kerala population have shown contradictory results in the distribution of cusp patterns in mandibular premolars.[30,31] The results of the present study also showed a predominance of 3 cusp type mandibular second premolars. The results of the present study show a similar trend to the results of the studies from other populations.[28,32-35] The 3 cusp pattern of the maxillary second molar (hypocone reduction) was observed in around 29% of the Jordanian population which is around 14.6%–18.5% in the present study.[36] Another odontometric study showed insignificant difference in the MD and BL dimensions of mandibular premolars between genders, which is contradictory to the present study. The

Table 7: The results of the Wilcoxon signed-rank test and the Mann–Whitney U test for the distribution of the number of cusps

Tooth number (FDI)	Number of cusps	Male *n* (%)	Male Percentage symmetry	Male Wilcoxon signed-rank test significant	Female *n* (%)	Female Percentage symmetry	Female Wilcoxon signed-rank test significant	Mann–Whitney U test significant
#44	2	56 (81.2)	97.1	0.157	77 (93.9)	97.6	0.157	0.016
	3	13 (18.8)			5 (6.1)			
#34	2	58 (84.0)			79 (96.3)			0.010
	3	11 (15.9)			3 (3.7)			
#45	2	17 (24.6)	87.0	0.739	35 (42.7)	81.3	0.467	0.021
	3	52 (75.4)			47 (57.3)			
#35	2	18 (26.1)			38 (46.3)			0.011
	3	51 (73.9)			44 (53.7)			
#17	3	10 (14.5)	91.3	0.014	18 (22.0)	85.4	1.000	0.242
	4	59 (85.5)			64 (78.0)			
#27	3	4 (5.8)			18 (22.0)			0.005
	4	65 (94.2)			64 (78.0)			

FDI: Federation dentaire internationale

Table 8: The results of discriminant analysis using the tooth metric values independent variables and gender as dependent variable

Variables	Unstandardized coefficients	Standardized coefficients	Absolute size of correlation	Constant	Centroids Male	Centroids Female	Wilks' lambda	Significant	Percentage of correct classification Male	Percentage of correct classification Female	Percentage of correct classification Overall
#44_BL	1.719	0.714	0.811	-21.999	1.13	-0.951	0.479	0.000	84.1	95.1	90.1
#44_MD	-0.267	-0.108	0.324								
#34_BL	0.899	0.391	0.813								
#34_MD	-0.701	-0.323	0.282								
#45_BL	-0.349	-0.175	0.561								
#45_MD	0.014	0.006	0.436								
#35_BL	-0.211	-0.104	0.589								
#35_MD	0.954	0.395	0.509								
#17_BL	0.239	0.205	0.494								
#17_MD	0.276	0.176	0.298								
#27_BL	0.089	0.056	0.447								
#27_MD	0.026	0.018	0.314								

BL: Buccolingual, MD: Mesiodistal

Table 9: The results of the discriminant analysis using the cusp number traits as independent variables and gender as dependent variable

Variables (cusps)	Unstandardized coefficients	Standardized coefficients	Absolute size of correlation	Constant	Centroids Male	Centroids Female	Wilks' lambda	Significant	Percentage of correct classification Male	Percentage of correct classification Female	Percentage of correct classification Overall
#44	-0.208	-0.067	0.478	-16.881	0.453	-0.381	0.851	0.001	60.9	61.0	60.9
#34	2.770	0.791	0.516								
#45	0.513	0.241	0.461								
#35	0.383	0.182	0.511								
#17	0.398	0.155	0.230								
#27	1.981	0.685	0.560								

stepwise discriminatory analysis in this study using the MD and BL dimensions of incisors, molars, and premolars showed 99.8% correct classification.[37] Study has also shown a better predictability of gender when the dimensions of both the maxillary and mandibular teeth are subjected to discriminant analysis.[38] In the present study, the MD and BL dimensions of only the mandibular premolars and max second molar showed 90.1% correct classification. The present study also utilized the cusp number traits in discriminating sexes. It was observed that the overall discriminating power of cusp number traits in

61%. A meta-analysis of studies related to the odontometric sex determination revealed that a small degree of sexual dimorphism exists in almost all human teeth. It was also observed that the second molars had better sex determination power than the first molar.[39] In the present study, we included the mandibular premolars and the maxillary second molar as they are the teeth that show maximum variations in the number of cusps. The number of cusps directly reflects on the crown size in both the MD and BL dimensions. We observed that the multiple lingual cusps are more frequently observed in males in all the three teeth. The distribution of number of cusps between genders is significantly different in all teeth except the maxillary right second molar. The sex determination using the cusp number trait is not as powerful as the metric traits. Nearly 61% of the overall cases were correctly classified based on the cusp number traits. Thus, it was observed that females were more correctly classified using the cusp number trait.

Conclusion

The discriminant analysis in discriminating the sexes based on the mesiodistal and the buccolingual dimensions of mandibular first and second premolar and maxillary second molar at a variance of around 85% had a hit ratio of 90.1% using this model. The cusp number traits have lesser discriminating power (61%) when compared to the metric parameters. The males had significantly wider mandibular premolars and maxillary second molars in both the BL and MD dimensions than those of females. The buccal cusps diameter in both the premolars was significantly greater in male than females.

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Conflicts of interest

There are no conflicts of interest.

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