Original Article

Diagonal tooth measurements in sex assessment: A study on North Indian population

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Abstract

Background: Sexual dimorphism has been of great interest to anthropologists and odontologists. Dental measurements are important in anthropology for the study of sexual dimorphism with most common being the traditional linear odontometric measurements. Apart from these, alternative dental measurements have been developed such as the crown and cervical diagonal diameters and mesiodistal and buccolingual cervical diameters of teeth. **Aims and Objective:** The primary objective of the following study is to assess the degree of sexual dimorphism in teeth of a North Indian population using the crown diagonal diameters and secondary is to evaluate the applicability of diagonal measurements in sex determination by means of discriminant functional analysis. **Materials and Methods:** The study sample comprised 200 individuals (100 males and 100 females) of an age group ranging from 18 to 57 years, in a North Indian population. The mesiobuccal-distolingual (MBDL) and distobuccal-mesiolingual (DBML) crown diameters of seven maxillary and seven mandibular teeth on the study models were measured using digital Vernier calipers. **Results:** The most dimorphic teeth amongst all for crown diagonal diameters are the maxillary central incisors and the least dimorphic are the maxillary second premolars. The mean diagonal crown dimensions in all but one tooth (DBML of maxillary lateral incisor) of males exceeded that of females. The difference was statistically significant in MBDL dimensions of maxillary and mandibular central incisor, canine, first and second molar and DBML dimensions of maxillary central incisor and maxillary and mandibular canine, first molar and second molar ($P < 0.05$). The accuracy of determination of sex by MBDL crown dimension ranges from 55% to 75% in males and 47-84% in females, while by DBML crown dimension ranges from 55% to 80% in males and 65-80% in females with the overall accuracy of sex determination ranging from 51% to 80% respectively. **Conclusion:** MBDL and DBML crown dimensions are reliable indicators and can be used along with or/and instead of linear measurements in sex determination. In situations in which it is difficult to take correct measurements of linear dimensions of teeth, these alternative odontometric measurements can be used consistently to determine sex.

Key words: Dimorphism, odontometrics, sex determination

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Introduction

Dental measurements are important in anthropology for the study of sexual dimorphism,[1-3] the trend toward tooth and jaw size reduction in Late Pleistocene/Early Holocene humans[4] and differences between past human populations.[5,6] Teeth are very resistant to post-mortem destruction and fragmentation in comparison to other hard tissues of the human body. They are therefore often used as a way of reconstructive surgery. This characteristic of teeth gives them an advantage for sex determination in forensic cases and mass graves, where bones are frequently fragmentary.[7]

"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.[3] Teeth sizes show some differences in both sexes and populations.[8] In general, the mesiodistal (MD) and buccolingual (BL) measurements of teeth are used in sex determination studies. Kieser has researched into sex determination by odontometric measurements and found significant differences between male and female teeth using MD and BL dimensions.[9] Crown diameters and combinations of root lengths are also used for measurements in sex determination.[10] One of the other common methods for sex determination is the mandibular canine index. It is possible to find a higher rate of discriminatory capability between sexes by using these measurements regardless of the differences existing among populations.[11,12] The variation among populations is the result of genetic and environmental factors. Therefore, collection of data from different populations is important for dental sexual dimorphism.[7]

Nevertheless, these dimensions are affected by attrition, cervical abrasions, interproximal wear facets, crowding, presence of dental calculus in the cervical third and it is difficult to take measurements when the teeth are still held in the tooth socket.[6,7] As a result alternative dental measurements were developed because they are less affected by these problems.[6] These measurements are the crown and cervical diagonal diameters and MD and BL cervical diameters of teeth.

The aim of this study was to assess the degree of sexual dimorphism in teeth of a North Indian population using crown diagonal diameters and to evaluate the applicability of diagonal measurements in sex determination by means of discriminant functional analysis.

Materials and Methods

The study sample comprised of 200 upper and lower jaw dental models, belonging to 100 males and 100 females of an age group ranging from 18 to 57 years in a north Indian population. The inclusion criteria were as follows: Fully erupted teeth from right permanent central incisor to right second molar, no fillings or extractions, no crowns, crowding of teeth, fractured teeth or orthodontic apparatuses and no developmental or orthodontic anomalies that could affect odontometric measurements.

Upon their approval of the procedure by an informed consent, the subjects upper and lower jaw impressions were taken with alginate material, which was followed by the preparation of their models by dental stone. Using these models, mesiobuccal–distolingual (MBDL) and distobuccal–mesiolingual (DBML) measurements of seven teeth on each jaw were taken separately. The upper and lower third molars were excluded. All the measurements were taken from the same side, which was usually the right side in these cases. In case of absence of the right tooth the dimensions of the left tooth were taken. The measurements were taken with a digital Vernier caliper (resolution 0.01 mm). When placing the caliper parallel to the occlusal surface, the following points were accepted as a guide during the measurements as defined by Hillson *et al*.[6]

MBDL crown diameter: The maximum distance from the mesiobuccal corner of the crown to the distolingual corner.

DBML crown diameter: The maximum distance from the distobuccal corner of the crown to the mesiolingual corner.

The measurements were performed by one person and all values were rounded to two decimal places. In order to assess the reliability of the measurements, intra-observer error was tested. The same measurements were obtained from 50 randomly selected casts from the original sample at a different time by the same observer to assess intra-observer error. Another observer measured the same randomly selected teeth in order to test the inter-observer error. Their measurements were analyzed using Student's t-test. There was no statistically significant difference between the findings of the two observers. Statistically significant sexual dimorphisms in male and female odontometric features were tested by the unpaired t-test. The level of statistical significance was set at $P < 0.05$.

The mean values of MBDL and DBML dimensions of males and females were subjected to the following formula[13] to calculate percentage of sexual dimorphism. The percentage of dimorphism is defined as the percent by which the tooth size of males exceeds that of females.

Percentage of sexual dimorphism = $([Xm/Xf] - 1) \times 100$

Where Xm = mean male tooth dimension; Xf = mean female tooth dimension.

Data obtained from various measurements was further analyzed using stepwise discriminant function statistics using SPSS version 10, (IBM) and Epi-Info 6.04 d software (CDC, Atlanta, US).

Results

A total of 28 measurements were taken on 14 teeth of each individual included in this study: Seven teeth from the upper jaw and seven from the lower. A total of 5600 measurements on the teeth of 200 individuals were accomplished and analyzed by SPSS program.

Sexual dimorphism

An independent two sample t-test was used to test whether males' means are significantly different from females'. Tables 1 and 2 show descriptive statistics, percentage sexual dimorphism, t values and P values for MBDL and DBML crown diameters respectively for the seven teeth of all males and females included in this study. In the MBDL crown diameter [Table 1], both maxillary and mandibular central incisor, canine, first molar and second molar showed a statistically significant difference between males and females ($P < 0.05$). Percentage sexual dimorphism was maximum for maxillary central incisor (7.4%) followed by maxillary and mandibular second molar (6.1%) and maxillary canine (5.8%) in MBDL crown diameters.

In the DBML crown diameter [Table 2], maxillary central incisor, maxillary and mandibular canine, first molar and second molar showed a statistically significant difference between males and females ($P < 0.05$). Percentage sexual dimorphism was maximum for maxillary central incisor (6.4%) followed by mandibular first molar (5.8%) and mandibular second molar (5.1%) in DBML crown diameters.

The most dimorphic teeth amongst all for crown diagonal diameters are the maxillary central incisors and the least dimorphic are the maxillary second premolars. The mean diagonal crown dimensions in all but one tooth (DBML of maxillary lateral incisor) of males exceeded that of females.

Stepwise discriminant function analysis

The differences between the sexes were analyzed by discriminant function statistics. Tables 3 and 4 depict standard coefficient, structure matrix, unstandardized coefficients, raw coefficient, group centroids and sectioning point for MBDL and DBML crown diagonal dimension respectively.

The standard coefficient shows the contribution of the respective variable to the discrimination between the two sexes. The structure matrix gives the correlations between the variables and discriminant functions. Group centroids are the mean discriminant score for each sex. These means can be used to determine the degree of separation between the two sexes. The sectioning point is the average of male and female group centroids. Unstandardized coefficient is used in the calculation of discriminant function score (y).

To assess the sex, tooth dimensions are multiplied with the respective unstandardized coefficients (b) and added to the constant (a). If the values (y) thus obtained were greater than the sectioning point the individual was considered a male and if less than the sectioning point the individual was considered female.

i.e. y = a + b (x)

where x is dimension of the tooth in centimeters.

Table 1: Descriptive statistics, % sexual dimorphism and *t* values of MBDL crown dimensions

Teeth	Mean±SD (*n*=100)		% sexual dimorphism	*t* value	*P* value
	Male	Female			
Maxillary teeth					
Central incisor	8.08±0.56	7.52±0.39	7.4	8.02	0.000**
Lateral incisor	6.47±0.51	6.41±0.40	0.9	0.839	0.403
Canine	8.07±0.65	7.63±0.57	5.8	5.07	0.000**
First premolar	8.87±0.49	8.76±0.52	1.3	1.63	0.103
Second premolar	8.93±0.64	8.81±0.62	1.4	1.35	0.177
First molar	12.61±0.52	12.04±0.69	4.7	6.51	0.000**
Second molar	11.79±0.61	11.11±0.75	6.1	7.04	0.000**
Mandibular teeth					
Central incisor	5.88±0.49	5.71±0.54	2.9	2.26	0.024*
Lateral incisor	6.16±0.51	6.04±0.34	1.9	1.82	0.071
Canine	7.12±0.62	6.79±0.53	4.9	4.04	0.000**
First premolar	7.89±0.54	7.83±0.64	0.7	0.697	0.487
Second premolar	8.33±0.50	8.22±0.56	1.3	1.44	0.151
First molar	12.10±0.58	11.50±0.55	5.3	7.56	0.000**
Second molar	11.36±0.64	10.70±0.49	6.1	8.12	0.000**

*Statistically significant at $P<0.05$, **Statistically highly significant at $P<0.001$. MBDL: Mesiobuccal distolingual; SD: Standard deviation

Table 2: Descriptive statistics, % sexual dimorphism and *t* values of DBML crown dimensions

Teeth	Mean±SD (*n*=100)		% sexual dimorphism	*t* value	*P* value
	Male	Female			
Maxillary teeth					
Central incisor	7.32±0.39	6.88±0.41	6.4	7.72	0.000**
Lateral incisor	6.15±0.58	6.17±0.52	0.4	−0.305	0.760
Canine	7.49±0.54	7.26±0.41	3.2	3.38	0.001*
First premolar	8.58±0.47	8.56±0.62	0.3	0.290	0.772
Second premolar	8.58±0.54	8.56±0.47	0.2	0.186	0.853
First molar	11.59±0.58	11.16±0.72	3.8	4.55	0.000**
Second molar	10.90±0.46	10.38±0.56	5	7.06	0.000**
Mandibular teeth					
Central incisor	5.53±0.40	5.42±0.47	2.1	1.84	0.067
Lateral incisor	5.77±0.43	5.75±0.34	4.3	0.450	0.654
Canine	6.51±0.69	6.30±0.51	3.3	2.40	0.017*
First premolar	7.30±0.58	7.26±0.69	0.6	0.447	0.655
Second premolar	7.97±0.54	7.94±0.70	0.4	0.335	0.738
First molar	11.49±0.47	10.85±0.45	5.8	9.58	0.000**
Second molar	10.83±0.73	10.31±0.57	5.1	5.65	0.000**

*Statistically significant at $P<0.05$, **Statistically highly significant at $P<0.001$. DBML: Distobuccal mesiolingual; SD: Standard deviation

With the help of the stepwise method, the crown diagonal measurements of the maxillary and mandibular teeth in the samples were analyzed separately. Since, the MBDL crown dimensions of maxillary and mandibular lateral incisor, first premolar and second premolar and DBML crown dimensions of mandibular central incisor, maxillary and mandibular lateral incisor, first premolar and second premolar did not show any statistically significant dimorphism, they were not subjected to further analysis. Table 5 shows the results of the analyses of crown diagonal diameters and accuracy rates. In this study, the accuracy of determination of sex by MBDL crown dimension ranges from 55% to 75% in males and 47-84% in females, while by DBML crown dimension ranges from 55% to 80% in males and 65-80% in females. The overall accuracy of sex determination ranged from 51% to 80% respectively. In the maxillary teeth accuracy for sex determination was highest (80%) for DBML crown dimension of central incisor and lowest (57.5%) for DBML crown dimension of first molar. In the mandibular teeth accuracy for sex determination was highest (72.5%) for DBML crown dimension of the first molar and lowest (51%) for MBDL crown dimension of central incisor.

Discussion

Teeth have been the focus of much research in the past[7,14-16] because they are the most durable tissue in the human body. A number of studies have examined dental pathology, morphology and odontometric variation.[7,17] However, in the forensic context, many researchers have focused on age estimation[16,18] and sex determination.[7,12,14,19] Teeth are usually retained in skeletal specimens and hence, can be used in sex differentiation. The dentition takes precedence particularly when preferred parameters such

Table 3: Canonical discriminant function coefficients for MBDL crown dimensions

Teeth	Standard coefficient	Structure matrix	Unstandardized coefficient	Raw coefficient (constant)	Group centroids		
					Male	Female	Sectioning point
Maxillary teeth							
Central incisor	1.000	1.000	2.036	−15.893	0.568	−0.568	0
Lateral incisor	1.000	1.000	2.141	−13.800	0.059	−0.059	0
Canine	1.000	1.000	1.622	−12.732	0.358	−0.358	0
First premolar	1.000	1.000	1.963	−17.314	0.116	−0.116	0
Second premolar	1.000	1.000	1.577	−13.993	0.096	−0.096	0
First molar	1.000	1.000	1.628	−20.067	0.460	−0.460	0
Second molar	1.000	1.000	1.460	−16.720	0.498	−0.498	0
Mandibular teeth							
Central incisor	1.000	1.000	1.925	−11.162	0.160	−0.160	0
Lateral incisor	1.000	1.000	2.274	−13.883	0.128	−0.128	0
Canine	1.000	1.000	1.724	−11.994	0.286	−0.286	0
First premolar	1.000	1.000	1.678	−13.202	0.049	−0.049	0
Second premolar	1.000	1.000	1.869	−15.468	0.102	−0.102	0
First molar	1.000	1.000	1.767	−20.857	0.535	−0.535	0
Second molar	1.000	1.000	1.750	−19.318	0.574	−0.574	0

MBDL: Mesiobuccal distolingual

Table 4: Canonical discriminant function coefficients for DBML crown dimensions

Teeth	Standard coefficient	Structure matrix	Unstandardized coefficient	Raw coefficient (constant)	Group centroids		
					Male	Female	Sectioning point
Maxillary teeth							
Central incisor	1.000	1.000	2.475	−17.581	00.546	−0.546	0
Lateral incisor	1.000	1.000	1.800	−11.092	−0.022	0.022	0
Canine	1.000	1.000	2.081	−15.358	0.239	−0.239	0
First premolar	1.000	1.000	1.807	−15.498	0.021	−0.021	0
Second premolar	1.000	1.000	1.946	−16.692	0.013	−0.013	0
First molar	1.000	1.000	1.510	−17.180	0.322	−0.322	0
Second molar	1.000	1.000	1.922	−20.457	0.499	−0.499	0
Mandibular teeth							
Central incisor	1.000	1.000	2.283	−12.509	0.130	−0.130	0
Lateral incisor	1.000	1.000	2.542	−14.649	0.032	−0.032	0
Canine	1.000	1.000	1.642	−10.526	0.170	−0.170	0
First premolar	1.000	1.000	1.557	−11.341	0.032	−0.032	0
Second premolar	1.000	1.000	1.590	−12.651	0.024	−0.024	0
First molar	1.000	1.000	2.145	−23.973	0.678	−0.678	0
Second molar	1.000	1.000	1.515	−16.017	0.400	−0.400	0

DBML: Distobuccal mesiolingual

Table 5: Accuracy of classification results of samples

Teeth	MBDL (*N* (%))			DBML(*N* (%))		
	Male	Female	Total	Male	Female	Total
Maxillary teeth						
Central incisor	64 (64)	70 (70)	134 (67)	80 (80)	80 (80)	80 (80)
Canine	57 (57)	70 (70)	127 (63.5)	55 (55)	65 (65)	120 (60)
First molar	75 (75)	55 (55)	130 (65)	55 (55)	60 (60)	115 (57.5)
Second molar	60 (60)	60 (60)	120 (60)	60 (60)	75 (75)	135 (67.5)
Mandibular teeth						
Central incisor	55 (55)	47 (47)	102 (51)			
Canine	60 (60)	65 (65)	125 (62.5)	55 (55)	70 (70)	125 (62.5)
First molar	70 (70)	65 (65)	135 (67.5)	75 (75)	70 (70)	145 (72.5)
Second molar	56 (56)	84 (84)	140 (70)	55 (55)	70 (70)	125 (62.5)

MBDL: Mesiobuccal-distolingual; DBML: Distobuccal-mesiolingual; *N*: Number

as the pelvis are unavailable and cranial and long bones fragmentary. However, since linear tooth measurements usually give moderate levels of accuracy in sex identification, alternative means of assessing sex within the realm of linear measurements needs investigation.[20] This study investigated whether univariate sexual dimorphism in diagonal crown diameters offered a solution.

Several studies of sexual dimorphism in teeth have shown that there are differences in tooth size between the two sexes.[7,12,14,21] The results obtained from crown diagonal diameters taken during the course of this study, showed that diagonal crown dimensions in all but one tooth (DBML of maxillary lateral incisor) of males exceeded that of females. The difference was statistically significant in MBDL dimensions of maxillary and mandibular central incisor, canine, first and second molar and DBML dimensions of maxillary central incisor and maxillary and mandibular canine, first molar and second molar. Karaman[12] in his study on diagonal teeth measurements in predicting gender in a Turkish population, found that seven of the fourteen measurements in the maxilla and ten of the fourteen measurements in the mandible showed significantly greater results in the males. Zorba *et al*.[7] in their study on sex determination in modern Greeks using diagonal measurements of molar teeth found that male molars are larger than female molars, which is in accordance with our study. The lateral incisor and premolars did not show any significant sexual dimorphism in the present study.

In the current study percentage sexual dimorphism was maximum for MBDL crown diameter of maxillary central incisor (7.4%) followed by DBML crown diameter of the same (6.4%) and minimum for DBML crown diameter of maxillary second premolar (0.2%) followed by DBML crown diameter of maxillary first premolar (0.3%). Zorba *et al*.[7] in their study amongst maxillary and mandibular molars found that crown DBML dimensions show more sexual dimorphism than crown MBDL dimensions. In the present study, crown diagonal diameters of both maxillary and mandibular second molars showed more dimorphism than first molars except DBML dimension of mandibular molar. These results were similar to the study conducted by Zorba *et al*.[7] Since the crown diagonal dimensions of maxillary and mandibular premolars, lateral incisors and DBML crown dimension of mandibular central incisor did not show any sexual dimorphism, thus this method is not reliable for sex determination using crown diagonal diameters for these teeth. However, the most studied dimensions for sexual dimorphism in teeth are crown MD and BL diameters. Although, these diameters present a high degree of sexual dimorphism, diagonal diameters have also been found to present higher or equal sexual dimorphism and can thus be considered a reliable method for sex determination. Hence, the alternative diagonal measurements can be used for sex determination along with or/and instead of crown MD and BL diameters where these cannot be taken. Hillson *et al*.[6] mentioned that the alternative measurements can be recorded at least as consistently and they are acceptable by the standards normally applied to dental measurements.

Amongst the teeth which were analyzed by discriminant functional analysis during the course of the study, the highest rate of accuracy was observed in DBML crown dimension of maxillary central incisor. The overall accuracy of sex determination ranged from 51% to 80% respectively. Maxillary central incisors showed the highest accuracy rate in the present study. The accuracy rates of canines and molars in diagonal measurements were not as high as that of maxillary central incisors. These results were in contrast to the study done by Karaman[12] who found canines to show the highest rate of accuracy amongst all the teeth.

In the current study, accuracy rate of sex determination was higher in females (9 of 15) than in males (2 of 15), while 2 crown diagonal dimensions showed equal accuracy for both females and males. These results were in concordance with the study conducted by Karaman[12] in Turkish population and Iscan and Kedici[22] who observed more dimorphism in female subjects. The maxillary teeth and mandibular teeth in the present study were found to be equally dimorphic, which was in contrast to previous studies[7,12] which found mandibular teeth to be more dimorphic. The difference in accuracy of sex determination between different populations is due to the fact that sexual dimorphism is population specific. On comparison of accuracy rate of determining sex amongst molars, it was observed that mandibular molars were more dimorphic than maxillary molars which was in unison with the study conducted by Zorba *et al*.[7]

Previous studies[20,21] indicate that MD and BL dimensions are more accurate in determining sexual dimorphism. In situations in which it is difficult to take correct measurements of MD and BL dimensions of teeth, these alternative odontometric measurements can be used reliably to determine sex.

Conclusion

The present study has described sexual dimorphism in crown diagonal diameters using univariate statistics and stepwise discriminant functional analyses. It was found that MBDL and DBML crown dimensions are reliable indicators and can be used along with or/and instead of linear measurements in sex determination. These can be useful in archeological, odontologic, genetic, forensic and crime investigations, as ethnicity/race, culture and environment are known to affect odontometrics.

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