EFFICACY OF "DIMODENT" SEX PREDICTIVE EQUATION ASSESSED IN AN INDIAN POPULATION

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ABSTRACT
Teeth are considered as a useful adjunct for sex assessment and may play an important role in constructing a post-mortem profile. The Dimodent method is based on the high degree of sex discrimination obtained with the mandibular canine and the high correlation coefficients between mandibular canine and lateral incisor mesiodistal (MD) and buccolingual (BL) dimensions. This has been evaluated in the French and Lebanese, but no study exists on its efficacy in Indians. Here, we have applied the 'Dimodent' equation on an Indian sample (100 males, 100 females; age range of 19-27yrs). Additionally, a population-specific Dimodent equation was derived using logistic regression analysis and applied to our sample. Also, the sex determination potential of MD and BL measurements of mandibular lateral incisors and canines, individually, was assessed. We found a poor sex assessment accuracy using the Dimodent equation of Fronty (34.5%) in our Indian sample, but the population-specific Dimodent equation gave a better accuracy (72%).Thus, it appears that sexual dimorphism in teeth is population-specific; consequently the Dimodent equation has to be derived individually in different populations for use in sex assessment. The mesiodistal measurement of the mandibular canine alone gave a marginally higher accuracy (72.5%); therefore, we suggest the use of mandibular canines alone rather than the Dimodent method.

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Keywords: Sex assessment; Dimodent equation; mandibular canines; mandibular lateral incisors; forensic odontology; Indians

Running Title: Dimodent equation in Indians

INTRODUCTION
Sex determination is an important aspect in post-mortem profiling and is especially useful in the identification of skeletal remains. Teeth, being resistant to a variety of post-mortem insults, are frequently used in comparative identification of human remains. The dentitions have also proved to be useful accessories in sex estimation. Additionally, since most teeth develop earlier than skeletal maturation, they can also serve as important sex determinants in young individuals.[1,2] Sex-related morphologic differences in the human skeleton have been extensively evaluated in several living and prehistoric populations. However, tooth associated odontometric differences have been less thoroughly investigated and mostly derive from the dentition of extinct populations.[3,4] Several studies have demonstrated that male teeth are generally larger than those of females in various populations.[5-11] However, the magnitudes and patterning of sexual dimorphism in permanent teeth differs from population-to-population. This could have a genetic basis and represent the cumulative effects of selection for sexual dimorphism per se.[12]

Canines, amongst all the teeth, have been shown to exhibit the maximum sexual dimorphism. They are sturdy teeth and more resistant to disease.[13] The canines are not only exposed to less plaque, calculus, abrasion from brushing, or heavy occlusal loads as compared to other teeth, but are also less severely affected by periodontal disease. Hence, they are usually the last teeth to be extracted, making them the "key teeth" for personal identification.[2,12-15]

Garn et al[12] studied sexual dimorphism by measuring the mesio-distal width of canines in different ethnic groups and concluded that the magnitude of canine tooth sexual dimorphism varied in different ethnic groups. Furthermore, the mandibular canines showed a greater degree of sexual dimorphism than the maxillary canines.[12] Sexual dimorphism was reported to be more pronounced for molars than premolars, but posterior teeth are generally less variable than the anterior teeth. Garn et al[12] attributed this to a "field" of sexual dimorphism that includes the teeth adjacent to canines as compared with the remote teeth of the same morphologic classes. Hence, the lateral incisor tends towards greater percentage dimorphism than does the central incisor, and the first premolar shows greater percentage dimorphism than the second premolar. Thus across genera, it appears that teeth adjacent to canines share with it a tendency for greater dimorphism; the greater the canine dimorphism, the greater the sexual dimorphism of adjacent teeth.[12] The Dimodent method is thus based on the high degree of sex discrimination obtained with the mandibular canine and the high correlation coefficients between mandibular canine and lateral incisor widths. It uses logistic regression analysis based on the mesiodistal and buccolingual width of these two teeth (the mandibular canine and lateral incisor). This was first applied on a French population by Fronty et al[17] and later by Ayoub et al[18] in the Lebanese population and has given moderate to good accuracy (76.7% and 90.6%, respectively). However, the equation has not been tested on Indians. Since, it is known that sexual dimorphism varies among populations,[3,5–7,9,12,16] we additionally ventured to develop a population-specific Dimodent formula for our sample. The present study sought to test the efficacy of the Dimodent equation of Fronty as well the population-specific equation in an Indian sample.

MATERIALS AND METHODS

The present sample included dentitions from 100 males and 100 females from India belonging to the age range of 19–27 years. The sample was limited to young adults to ensure that the teeth were intact in order to obtain optimal odontometric information. Subjects were from different states of India and belonged to a mixture of ethnic groups, religions and castes so as to evaluate the sex differences in Indians in general. After obtaining verbal informed consent, maxillary and mandibular alginate impressions were made and casts were poured using dental stone.

Measurements: Mesiodistal (MD) and buccolingual (BL) dimensions of mandibular canines and mandibular lateral incisors were measured on the casts using a digital calliper with calibration of 0.01mm (Mituyoto, Japan). The MD dimension was defined as the greatest distance between the contact points on the proximal surfaces of the tooth crown. In case of tooth rotation or malposition, the measurements were obtained between points where it was considered that contact with adjacent teeth would have occurred. The BL dimension was defined as the greatest distance between the labial surface and the lingual surface of the tooth crown, measured with the calliper beaks held at right angles to the MD dimension. Measurements were repeated by a second observer on 20 randomly selected casts to test for possible inter-observer variation. Since the dimensions on right and left sides of the same dental arch are usually symmetrical,[6] the right side measurements only were taken into consideration for the present study.

Application of the Dimodent equation of Fronty: The measurements undertaken were subjected to the Dimodent sex prediction equation of Fronty et al[17] which is formulated as follows:

$P = 1/(1+e^{-y})$, where P stands for the probability of the teeth belonging to a male or female.

y is calculated as follows:

$y = 24.2 + (1.54 \cdot \text{LI-MD}) + (1.92 \cdot \text{LI-BL}) – (2.84 \cdot \text{C-MD}) – (3.38 \cdot \text{C-BL})$ (A)

LI-MD — mesiodistal dimension of the mandibular lateral incisor

LI-BL — buccolingual dimension of the mandibular lateral incisor

C-MD — mesiodistal dimension of the mandibular canine

C-BL — buccolingual dimension of the mandibular canine

According to the obtained P values, three options are possible:

1. If P tends towards 100% (i.e., P > 50%), the dentition would belong to a male
2. If P tends towards 0% (i.e., P < 50%), the dentition would be that of a female;
3. If P = 50%, discrimination is null, and sex cannot be assessed.

Deriving a population-specific Dimodent equation for Indians: The measurements were entered into an MS Excel spreadsheet (Microsoft Corp., Redmond, Washington, USA) and logistic regression analysis (LRA) was performed for MD and BL measurements of mandibular lateral incisors and canines, as well as for the absolute measurements individually. Sex identification was determined by the following:

$P = 1/(1+e^{-y})$

Y is calculated as follows: $Y = -19.112 + (0.069 \cdot \text{LI-MD}) - (0.382 \cdot \text{LI-BL}) + (2.188 \cdot \text{C-MD}) + (1.030 \cdot \text{C-BL})$ (B).

Statistical Analyses: The possible sex variation in MD dimensions of right mandibular canines and mandibular lateral incisors was evaluated using the independent samples t-test while the inter-observer differences were tested using the paired t-test. The LRA were performed on SPSS 16.0 software package (SPSS Inc., Chicago, Illinois, USA). The arithmetic calculations for calculating sexual dimorphism using the Dimodent equation, as well as the population-specific equation, were undertaken on an MS Excel spreadsheet.

RESULTS

Table 1 depicts the descriptive statistics and degree of sexual dimorphism for MD and BL measurements of mandibular canines and lateral incisors. We obtained statistically significant differences ($p < 0.05$) between males and females for MD dimensions of mandibular canines and mandibular lateral incisors. The paired t-test evaluating the potential inter-observer variation showed insignificant statistical differences for all the measurements (Table 2).

The accuracy of sex prediction from the Dimodent equation in the present study ranged from 3% for females to 66% for males. Overall the application of this equation was successful in sex prediction in 34.5% of the Indian sample (Table 3). The accuracy of the Indian equation ranged from 69% for males to 75% for females, with an overall success of 72% (Table 3). Additionally, the LRA of individual tooth measurements showed that the MD dimension of canine gave the best sex predictive accuracy (Table 4), followed by the BL dimension of canine, the BL dimension of lateral incisor and MD dimension of lateral incisor.

Table 1: *Descriptive statistics and t-values for the male and female mandibular canines and lateral incisors*

Variable	Female Mean (±SD)	Male Mean (±SD)	t value	p value
MD dimension of mandibular lateral incisor	5.8 (±0.35)	5.9 (±0.40)	3.174	0.002*
BL dimension of mandibular lateral incisor	5.6 (±0.49)	5.9 (±0.53)	5.354	0.000*
MD dimension of mandibular canine	6.5 (±0.37)	6.9 (±0.41)	6.639	0.000*
BL dimension of mandibular canine	6.6 (±0.55)	7.1 (±0.67)	5.729	0.000*

* Statistically significant at $p < 0.01$.

Table 2: *Descriptive statistics and t values for multiple observations*

Variable	Observer I Mean (±SD)	Observer II Mean (±SD)	Difference of Mean (±SD)	t val	p val
MD dimension of mandibular lateral incisor	5.85 (±0.47)	5.72 (±0.45)	0.13 (±0.67)	0.912	0.373
BL dimension of mandibular lateral incisor	5.94 (±0.50)	5.81 (± 0.49)	0.13 (±0.89)	0.675	0.508
MD dimension of mandibular canine	6.77 (±0.51)	6.73 (±0.55)	0.04 (±0.77)	0.269	0.791
BL dimension of mandibular canine	6.72 (±0.63)	6.61 (±0.64)	0.11 (±1.01)	0.484	0.634

DISCUSSION:

Sex determination is a first step in reconstructive identification in the field of forensics. In general, the sex of an unidentified person can be determined based on the anatomical characteristics of the external genitalia. However bones and teeth are the only available materials for sex determination in some instances such as markedly decayed or skeletonised remains. The study of teeth has been a subject of interest to anthropologists, biologists and forensic experts, as they are generally preserved even when the other bony structures have been destroyed. They are highly resistant to post-mortem insults, surviving a variety of destructive effects caused by trauma and incineration. Sexual dimorphism in tooth size has been explored recently with most authors concentrating on the use of BL and MD dimensions. These are easy to obtain and have demonstrated high degrees of sexual dimorphism in various studies.[8,9,12,14]

Furthermore, it is reported that tooth size is greatly influenced by genetics. Therefore, such measurements are considered to be population-specific and do not apply to the world at large.[12] Such odontometric data in sexing, especially in this part of Asia, has not been extensively studied. The present study sought to apply the Dimodent sex predictive equation given by Fronty et al[17] (A) on an Indian sample to test its efficacy. The overall accuracy of this equation in our sample was only 34.5%, with 66% of males and a mere 3% of females being correctly identified. In comparison, this equation gave a high predictive accuracy of 90.6% in the French[17] and moderate accuracy in the Lebanese (76.7%)[18] demonstrating the population-specific differences in the tooth dimensions as well as sexual dimorphism in various populations. The equation especially showed a poor accuracy in sexing females in our sample, and is similar to the findings of Acharya and Mainali,[2] who attributed it to relatively larger tooth dimensions of females. This could have resulted in poor identification of females when compared to previous studies, thus decreasing the overall sex discrimination potential of the equations.[2] This is corroborated by Prabhu and Acharya,[6] who said that the magnitude of sexual dimorphism in tooth dimensions in Indians is lower when compared to populations from other continents. This could be due to varied interactions between different genetic and environmental factors, resulting in large variations in the magnitude of sexual dimorphism across populations. Consequently, the Dimodent equation of Fronty et al[17] established on a French population gave poor sex assessment accuracy in Indians.

Therefore, we derived a Dimodent equation for our sample using LRA. This population-specific equation (B) was then evaluated on our sample, which vastly improved predictive accuracy to 72%; with 75% of males and 69% of females being correctly identified (Table 3).

Table 3: *Comparison of the accuracy of sexing the present sample using Dimodent equation of Fronty and population-specific dimodent equation*

Equation	Males		Females		Total	
	N	%	N	%	N	%
Dimodent equation of Fronty et al[17]	66/100	66	3/100	3	69/200	34.5
Present sample	75/100	75	69/100	69	144/200	72%

Additionally, each measurement of both teeth was also analysed with LRA. Surprisingly, the MD measurement of canines alone gave a predictive accuracy of 72.5% with 77 % of males and 68% of females being correctly identified (Table 4). This was marginally greater to that of the population-specific Dimodent equation (B) (Table 3) and suggests that the magnitude of sex differences in the Dimodent equation comes predominantly from the canine and the use of other teeth may result in a slightly lower accuracy. Canines differ from other teeth with respect to survival and sex dichotomy. These differences are probably related to their function, which is different on an evolutionary basis from other teeth.[2,13] It is postulated that canines are not primarily masticatory in function but are usually related to threat of aggression especially in primates. In humans, this aggressive function was gradually transferred to fingers from teeth; however, until then, males largely depended on canines for their survival. Consequently, in modern humans too, it is not by chance that canines are the teeth that demonstrate the maximum sexual dimorphism.[2,8,12,18–20] While the use of canines alone makes sex estimation straightforward and expedient, the efficacy may be of moderate nature (72%). Indeed, a recent study by Acharya et al[21] has shown high sex identification accuracy (100%) in Indians using LRA of all teeth and demonstrated its potential for use as the sole indicator of sex. As an analogy, the use of all teeth in our sample may further increase sex predictive accuracy, which we intend to explore in the near future.

Table 4: *Sex classification accuracy using logistic regression analysis of individual teeth.*

Variable	Male		Female		Total	
	N	%	N	%	N	%

MD dimension of mandibular lateral incisor	60/100	60	54/100	54	114/200	57
BL dimension of mandibular lateral incisor	59/100	59	59/100	59	118/200	59
MD dimension of mandibular canine	77/100	77	68/100	68	145/200	72.5
BL dimension of mandibular canine	63/100	63	63/100	63	126/200	63

CONCLUSION

This study supports the notion that sexual dimorphism in teeth is population-specific as the application of Dimodent equation of Fronty et al[17] gave very poor sex classification accuracy (34.5%) in Indians. The population-specific Dimodent equation, however, gave an accuracy of 72% suggesting that, if used, the Dimodent equation needs to be population-specific. Further, in our study, it was revealed that LRA using MD dimensions of mandibular canines alone gave marginally better results to that of the population-specific Dimodent equation, suggesting that canines be used independently (rather than the use of the Dimodent equation and the method therein of using mandibular lateral incisors with canines). But even this is still suboptimal (72.5%) and the use of all teeth (when present) may be better suited for sex prediction in forensic contexts with these methods.

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