Original Article

Sexual Dimorphism Using Odontometrics among the Pediatric Population of Erode District: A Population Study

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Abstract

Background: Forensic science often uses the skeletal, dental remains as sources for human identification. Sexual dimorphism is the systematic difference in form between males and females of the same species. This study is designed to compute a new formula for sex determination using discriminant function analysis in the deciduous crown dimensions of a paediatric population of Erode district.
Methodology: The sample consisted of 146 females and 218 males of South Indian origin aged between 3 and 5 years. Alginate impressions of the upper and lower dental arch were made and casts were poured immediately. A digital vernier calliper was used to obtain measurements. Teeth considered for measurement were all deciduous teeth. Statistical analysis was performed using the Statistical Package for the Social Science version 21.0 software (SPSS Inc., Chicago, IL, USA).
Results: By using the Student t-test, the different predictor variables of teeth selected between male and females were found to be significant ($P < 0.05$). Significant sexual dimorphism was found in Lower canine Bucco lingual (LCBL), Upper central incisor Bucco lingual (UCIBL), Upper 2nd molar Bucco lingual (UM2BL) and Upper lateral incisor Distal (ULIMD).
Conclusion: The formula derived from the present study could be of great value in sex determination of paediatric populations of Erode district.

Key Words: *Deciduous teeth, Dimorphism, Discriminant function analysis, Sex determination*

Introduction

Forensic science often uses the skeletal, dental remains as sources for human identification; in particular, the teeth are unique as they are always protected in a hard casting.[1] They are tissues characterized by structures with extraordinary resistance to putrefaction and effects of external agents that cause destruction of soft tissues of the body. Hence, teeth form an excellent structure for forensic investigation.[2]

Sexual dimorphism is the systematic difference in form between males and females of the same species. Identification of sex is more significant in narrowing down a victim. It allows the exclusion of one-half of the population, thereby aiding a more precise search for the identity of the deceased.[3]

Sexual dimorphism in the dental tissue is of monumental value to the physical anthropologist due to its applications in forensic identification.[4] Odontometric data provide insignificant trait differences among and within a population but form a stronger evidence for identification purposes.[5]

These differences not only reflect the ongoing process of evolution and provide a method for studying the evolutionary mechanism but also represent the variation that must be considered in the daily care of patients.[6]

Conventionally, mesiodistal (MD) and buccolingual (BL) diameters of the crowns of teeth form the basis for assessing sex differences. Several studies have been conducted, which demonstrated significant sexual dimorphism in dimensions of permanent[7-11] and deciduous crowns using diagnostic dental casts.[12-18]

This study emphasizes the importance of teeth in sexual dimorphism for the following reasons: (1) the pelvis, which is the most precise structural indicator, may be fragmented, (2) sex characteristics in pediatric bone are not fully developed and (3) DNA analysis can give precise results but is expensive and relatively time-consuming.[19]

If sexual dimorphism in deciduous dentition is proved for its significance in sex determination like permanent dentition,[7-11]

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then, it could be useful to precisely identify the sex of the children. Deciduous dentition-based studies have been carried out by Black TK,[20] De Vito and Saunders,[21] and Zadzinska *et al*.;[22] they have published a series of discriminant functions for sex determination. On a thorough search of the literature in the English language, there is, however, no such evidence explored in the Indian population for deciduous dentition.

The magnitude and pattern of sexual dimorphism in the size of teeth differ from one population to another. Hence, there is a need for finding out differences in the odontometric parameters in deciduous dentition among males and females of Indian natives with discriminant function, which may aid in establishing sex in juveniles.

MD, BL, and the diagonal measurements of deciduous teeth of canines and molars were recorded in previous studies.[20-25] However, the present study considered all the teeth with intercanine width (ICW) and intermolar width as a predictor variable in determining sex, and it was applicable in deriving the discriminant functions. To the best of our knowledge, this is a maiden attempt. The present study aimed to compute a new formula using discriminant function analysis and to verify the accuracy of such methods in sex determination from deciduous dentition in children of Erode district from South Indian origin.

Materials and Methods

Sample selection

The study sample consisted of 364 children who were selected from 940 subjects aged between 3 and 5 years of South Indian origin by simple random sampling method. Among the selected 146 were girls and 218 were boys. The sample for the study included teeth that were fully erupted which had no caries, restorations, or any history of orthodontic treatment and subjects with full complement of deciduous dentition was only considered others who were excluded from the study. The study was approved by the Institutional Ethical Committee, Namakkal district, Tamilnadu state, India.

Procedures and parameters

Alginate impressions (Tropicalgin, Zhermack Clinical, New Jersey, U. S. A.) of both the upper and lower dental arch were made using perforated trays and casts were poured immediately with type IV dental stone. A digital vernier caliper calibrated to an accuracy of. 01 mm (Mitutoyo Absolute Digimatic Sliding Caliper, Tokyo, Japan, 05 mm resolution) was used for obtaining the measurements. All the 20 deciduous teeth in the upper and lower arch were considered for measurements [Figure 1].

The incisors and canines were measured in two dimensions, the MD diameter and the BL diameter, and the molars in four different dimensions which included the MD diameter, the BL diameter along with the diagonal measurements such as mesiobuccal to distolingual (MBDL) diameter and distobuccal to mesiolingual (DBML) diameter. Two more measurements such as ICW and intermolar width for both first and second molar were recorded. For both upper and lower arches, the mean value was taken for left and right side and entered as

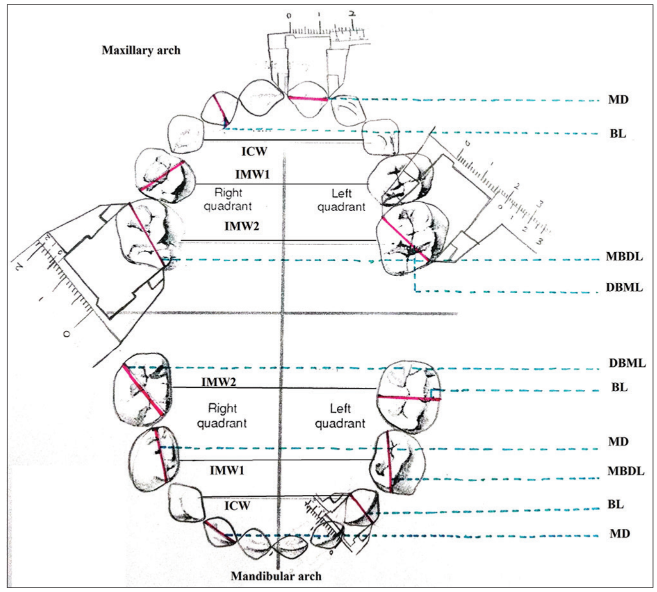

Figure 1: Line diagram showing the maxillary and mandibular arch with different variables and measuring methods followed using the Vernier calipers

one value for each tooth. All measurements were recorded by one of the investigators, and calibration was done by the senior author. For a rotated or malposed tooth, the measurement was made between points on the proximal surfaces of the crown where it was perceived that contact with the adjacent teeth would normally occur. A total of 34 parameters were used as a predictor variable which includes 17 variables for maxillary and mandibular arches, respectively.

The 17 variables included were MD and BL measurements of central incisor (CI), lateral incisor (LI), canine (Ca), first molar (D), and second molar (E) which accounted for 10 variables. Two diagonal measurements such as MBDL diameter and DBML diameter were recorded for both first molar (D) and second molar (E). ICW, intermolar width at first molar and intermolar width at second molar were also recorded which accounted for the other 7 variables.

Reliability measures

To estimate intraobserver variability, a second determination was made after 2 months by the same investigator. Intraclass correlation coefficient (ICC) was used to access the intraobserver variability. The ICC for all the measurements was 0.896 (93% confidence interval: 0.872–0.92), indicating that the difference attributed to the measurement error was very small or practically nonexistent.

Statistical analysis

Statistical analysis was performed using the Statistical Package for the Social Science version 17.0 software (SPSS Inc., Chicago, IL, USA). Descriptive statistics (mean and standard deviation) was computed for each variable, and Student's *t*-test was used to determine if statistically significant differences existed between the sexes. The level of significance was kept at $P < 0.05$. All the predictor variables were subjected to stepwise discriminant function analysis, which has the potential to optimally separate the sexes; further the statistical significance

Table 1: Student *t*-test for the comparison of all the predictor variables between both the sexes

Arch	Tooth	Variable	Male	Female	Difference	*t*-test	Sig
Upper (U)	Central incisor (CI)	MD	6.52±0.83	6.46±0.65	0.05425	0.488	0.626
		BL	4.70±0.66	4.89±0.77	-0.18633	-1.810	0.072
	Lateral incisor (LI)	MD	5.24±0.55	5.12±0.41	0.11596	1.594	1.594
		BL	4.33±0.65	4.28±0.72	0.04775	0.484	0.629
	Canine	MD	6.30±0.51	6.21±0.59	0.09213	1.161	0.247
		BL	5.44±0.65	5.57±0.75	0.13558	-1.353	0.178
	1st Molar	MD	7.05±0.50	6.92±0.49	0.12675	1.754	0.081
		BL	8.06±0.74	7.99±0.96	0.07554	0.622	0.535
		MBDL	7.00±1.72	6.58±1.61	0.41913	1.727	0.086
		DBML	6.66±1.56	6.50±1.29	. 15825	0.751	0.453
	2nd Molar	MD	8.86±0.62	8.76±0.66	0.09779	1.050	0.295
		BL	9.37±0.71	9.15±0.74	0.22100	2.105	0.037
		MBDL	8.32±2.36	7.71±2.14	0.61238	1.864	0.064
		DBML	7.76±1.84	7.43±1.74	0.32888	1.262	0.208
	Jaw transverse measurement	ICW	33.11±2.58	32.28±4.12	0.82326	1.735	0.084
		IM1W	41.57±2.67	40.77±2.43	0.79308	2.129	0.034
		IM2W	48.62±3.40	48.02±3.02	0.60563	1.289	0.199
Lower (L)	Central incisor (CI)	MD	4.11±0.51	4.10±0.59	0.01176	0.150	0.881
		BL	3.75±0.73	3.91±3.62	-0.16637	-0.489	0.625
	Lateral incisor (LI)	MD	4.59±0.51	4.57±0.42	0.01238	0.177	0.860
		BL	3.98±0.83	3.87±0.59	0.11105	1.025	0.307
	Canine	MD	5.49±0.54	5.38±0.45	0.10471	1.427	0.155
		BL	5.05±0.82	4.77±0.54	0.27379	2.626	0.009
	1st Molar	MD	7.46±0.61	7.49±0.70	-0.03258	-0.347	0.729
		BL	6.87±0.72	6.84±0.66	0.02442	0.242	0.809
		MBDL	6.92±1.46	6.61±1.46	0.30987	1.471	0.143
		DBML	6.71±1.30	6.29±1.49	0.42017	2.109	0.036
	2nd Molar	MD	9.68±0.58	9.52±1.02	0.16417	1.434	1.434
		BL	8.75±0.67	8.62±0.78	0.13438	1.287	0.200
		MBDL	8.42±1.92	8.09±1.93	0.32761	1.177	24.1
		DBML	8.43±1.86	8.12±1.94	0.31337	1.149	0.252
	Jaw transverse measurement	ICW	27.03±5.46	26.70±2.83	0.33045	0.495	0.621
		IM1W	35.08±2.06	35.23±2.46	-0.15008	-0.466	0.642
		IM2W	43.70±2.02	43.71±2.50	-0.02354	-0.073	0.942

Table 2: Stepwise discriminant function analysis

Stepwise Discriminant Function Analysis: Variables Entered/Removed[a,b,c,d]									
Step	Entered	Wilks' Lambda							
		Statistic	df1	df2	df3	Exact F			
						Statistic	df1	df2	Sig.
1	LCBL	0.965	1	1	196.000	7.137	1	196.000	0.008
2	UCIBL	0.939	2	1	196.000	6.375	2	195.000	0.002
3	UM2BL	0.885	3	1	196.000	8.368	3	194.000	0.000
4	ULIMD	0.863	4	1	196.000	7.692	4	193.000	0.000

At each step, the variable that minimizes the overall Wilks' Lambda is entered.[a,b,c,d] [a]Maximum number of steps is 68. [b]Minimum partial F to enter is 3.84. [c]Maximum partial F to remove is 2.71. d. F level, tolerance, or VIN insufficient for further computation

was assessed using Wilks' lambda. The variables having the higher discriminant function coefficient were included in the discriminant function for developing the formula.

$$DFS = C + df_1x_1 + df_2x_2 + \ldots + df_nx_n$$

Where DFS is the discriminant function score, df is the discriminant function coefficient, x is the score of the predictor variable, n is the sample size, and C is the discriminant function constant.

Results

The intraobserver reliability calculated during the second examination after 2 months revealed the ICC value to be 0.896. Hence, the measurements made at two different points showed

Table 3: Wilks' Lambda

Step	Number of variables	Lambda	df1	df2	df3	Exact F			
						Statistic	df1	df2	Sig.
1	1	0.965	1	1	196	7.137	1	196.000	0.008
2	2	0.939	2	1	196	6.375	2	195.000	0.002
3	3	0.885	3	1	196	8.368	3	194.000	0.000
4	4	0.863	4	1	196	7.692	4	193.000	0.000

Table 4. Overall Wilk's lambda to test the significance among the predictor variables

Test of function (s)	Wilks' Lambda	Chi-square	df	Sig.
1	0.863	28.696	4	0.000

Table 5: Conical discriminant function co-efficient of the entered predictor variables

Entered variables	Function 1
UCIBL	-1.277
ULIMD	0.879
UM2BL	1.080
LCBL	0.824
(Constant)	-12.553

negligible difference. Therefore, the initial measurements were taken into consideration for calculation.

In the observed mean dimensions, male values were higher than the female values except for certain parameters. The different predictor variables of teeth selected between male and females were subjected to Student's *t*-test and the significant ($P < 0.05$). Statistically significant difference was found among four parameters. The parameters were upper 2nd molar BL (UM2BL), upper 1st molar intermolar width, lower canine BL (LCBL) BP, and lower 1st molar DBML [Table 1].

A stepwise discriminant function analysis was performed for all the predictor variables by enter method. At each step, the variable that minimizes the overall Wilks' Lambda is entered with a maximum of 68 steps. Out of these, only four parameters were qualified for functional analysis which included LCBL, upper CI BL (UCIBL), and BP (UM2BL and ULIMD [Table 2].

Further, the parameters included in the functional analysis were checked for stepwise entry of Wilk's Lambda and assessed for its significance, and it was also found that they were highly statistically significant with $P < 0.005$ [Table 3]. The overall Wilk's Lambda for all the predictor variables were calculated and it showed a very high statistically significant value among the parameters with $P < 0.001$ [Table 4].

Table 5 shows the conical discriminant function coefficient values for the predictor variables which entered the functional analysis by Wilk's Lambda and the corresponding discriminant function constant.

Table 6: Group centroid for both the sex using unstandardised canonical discriminant functions

Functions at Group Centroids	
Sex	Function 1
Male	0.324
Female	-0.488

Table 7: Classification accuracy checked using cross validation for the developed discriminant function

Classification Results[a,c]			
Sex	Predicted Group Membership		Total
	Male	Female	
Original			
Count			
Male	196	22	218
Female	20	126	146
%			
Male	90.0	10.0	100.0
Female	13.7	86.3	100.0
Cross-validated[b]			
Count			
Male	185	33	218
Female	24	122	146
%			
Male	85.0	15.0	100.0
Female	16.3	83.7	100.0

[a]88.15% of original grouped cases correctly classified. [b]Cross validation is done only for those cases in the analysis. In cross validation, each case is classified by the functions derived from all cases other than that case. [c]84.35% of cross-validated grouped cases correctly classified

The discriminant analysis produced the best discriminant functions and the predictor variables included in the functions were Lower canine Bucco lingual (LCBL), Upper central incisor Bucco lingual (UCIBL), Upper 2nd molar Bucco lingual (UM2BL), and Upper lateral incisor Mesio Distal (ULIMD) based on the greatest univariate discriminant coefficient [Table 5]. Before the formula was calculated with the greatest univariate discriminant coefficient, the predictor variables were subjected to a test of significance using Wilks' lambda. It was found that the entire assigned predictor variables showed statistical significance at $P < 0.05$ [Table 4].

The best discriminant function was

$$DFS = -12.553 - 1.277\ (UCIBL) + 0.879\ (ULIMD) + 1.080\ (UM2BL) + 0.824\ (LCBL)$$

From the stepwise discriminant analysis, the group centroid was also generated for both the sexes. A group centroid is the mean discriminant score for each sex. A cut-off point, which separates one sex from the other, is the average of the two centroids; a smaller value than this is considered as a female and vice versa. The cut-off point between the sexes was −0.082. The male group centroid was 0.324 and the female group centroid was -0.488 [Table 6]. Raw coefficients, the discriminant function coefficients, were used to calculate the discriminant score.

The value obtained using discriminant function for the casts of males and females is calculated, respectively. Hence, it shows that this discriminant function formula can accurately identify sexual dimorphism in this population. To assess whether it is possible to generate accurate sex models from the data collected for this study, discriminant functions were calculated and tested using cross-validation. This was performed using SPSS software and the leave-one-out method was chosen to calculate the cross-validation error rate [Table 7].

The discriminant function used in the present study describes the optimal separation between the sexes and also shows that there are significant variations between them and it is substantiated by classification accuracy of functions provided in Table 7. Hence, the original grouped cases correctly classified were 88.15%.

Discussion

Sexual dimorphism in the size of deciduous dentition varies population to population, and hence, the criteria set for one population may not be applicable to another. Considering the fact that there are differences in odontometric features in specific populations, even within the same population in the historical and evolutional perspective, it is necessary to determine precise population values to make identification possible on the basis of dental measurements. These values can be of use in determining sex in specific cases: in individuals as well as in groups (mass disasters and archeological sites).[24]

The coronal morphology and dimension of a deciduous dentition remain unchanged during growth and development except for specific conditions such as nutritional abnormality, inherited disorders, and other pathological conditions. Hence, odontometric features can be used in determining the sex after the tooth has erupted even in child skeletons or samples whose skeletal features are not defined.[26]

The study of dental stone models has been in use in forensic odontology for a very long time. The accessibility to measure various dimensions using geometric devices is simpler and easier using dental stone models rather than direct intraoral measurements. Dental stone models serve a greater purpose for the diagonal and intra-arch measurements in particular.

When it is difficult to measure the MD width of the anterior teeth, diagonal measurements may be a reliable alternative.[27] In the present study, we considered the diagonal and intra-arch measurements also as a predictor variable in determining the sex. Hence, this variable will be of greater use in sex determination when malpositions such as tooth rotation, crowding, and orthodontical anomalies may cause difficulty in recording width measurements. This is a maiden study in using the intra-arch measurements in deciduous dentition for sex determination.

The limitations associated with the previous studies were that they have not included all the teeth and jaws; however, here in this current study, both upper and lower jaws with all the teeth are considered.

In the present study, it has been identified that significant sex differences exist in odontometric features of upper compared to the lower deciduous teeth. It was also found that these differences were large enough to determine the sex with classification accuracy between 85.0% and 83.7% from cross-validation of discriminant function analysis for male and female, respectively, when using all the parameters explained in the methodology.

In the present study, BL dimension contributes more to the sexual dimorphism compared to other parameters, that is, BL of upper CI and second molar as well as BP of lower canine. MD dimension of upper LI also significantly contributed to the same. This finding was entirely different from the study conducted in a south Indian population, where MD dimension of upper second molars, BL dimension of upper canine, and other diagonal measurements contribute more to sexual dimorphism compared to the current study.[24]

The equation developed by this study ranges in accuracy from 85% to 83.7%. This was considerably higher when compared to that developed by Black,[20] DeVito and Saunders[21] and Zadzinska *et al*.[22] with 33.3 to 75%, 35.7 to 45.9% and 38.5 to 73.3%, respectively and similar to the study conducted by Shankar S *et al*.[23]

This shows that the present study provides robust evidence to identify the sex in a paediatric population using its formula. The tooth that shows the greatest degree of sexual dimorphism was not the same when different studies were analysed. For example, in studies by Margretts and Brown,[12] Black[20] and Zadzinska *et al.*,[22] it is the BL dimension of the mandibular first molar, whereas in a study by Cardoso,[28] it is the MD dimension of the mandibular second molar that shows the greatest degree of sexual dimorphism compared to the present study where the BP dimension of the maxillary CI and second molar with BP dimension of mandibular canine shows the greatest percentage of sexual dimorphism.

Such population variations may result from differences in the quality of environment during growth and development, particularly maternal health, which may influence tooth size. Garn *et al*.[29] have revealed that children with low birth weight and low birth length show notably smaller deciduous tooth crowns. Similarly, Seow and Wan[30] have shown the smallest deciduous crown dimensions in very low birth weight children compared to normal birth weight children who show the largest, with the low birth weight revealing intermediate dimensions. Poor environmental conditions during prenatal life, in addition to reducing overall tooth crown size, also diminish sex differences, with males being affected most remarkably.

Conclusion

The present study elicits the fact that the level of sexual dimorphism in deciduous crown dimensions of an Indian population is sufficiently large enough for determining sex to an accuracy of 83.7%–85% from discriminant function analysis using all variables. Hence, the discriminant function derived would help in sex determination in a pediatric population of South Indian origin by substituting the odontometric values in the function and referring it to the cut-off point which discriminates the sex.

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Conflicts of interest

There are no conflicts of interest.

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