Sex determination using maxillary arch width of pediatric population of Namakkal district, India: A forensic study

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Abstract

Aim and Objectives: The aim of the study is to compute a new formula for sex determination using maxillary arch width of a pediatric population of Namakkal district.

Materials and Methods: The sample consisted of 146 females and 218 males of South Indian origin aged between 4 and 6 years. Alginate impressions of the upper and lower dental arch were made, and casts were poured immediately. A digital vernier caliper was used to obtain measurements. Arch width at canine, first molar and second molar for both maxilla and mandible were considered for measurement. Statistical analysis was performed using the Statistical Package for the Social Sciences Version 20.0 software.

Results: The Student's *t*-test was used to find out the significance between male and female among the different predictor variables at $P < 0.05$. Significant sexual dimorphism was found in maxillary intercanine width and maxillary first and second intermolar width with conical discriminant function coefficient of 0.732, −0.177 and −0.244, respectively.

Conclusion: The formula derived from the present study could be of great value in sex determination of pediatric populations of Namakkal district.

Keywords: Arch width, dimorphism, discriminant function analysis, sex determination

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INTRODUCTION

Forensic science often uses the skeletal, dental remains as sources for human identification; in particular, the teeth and jaw 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, the teeth and jaw form an excellent structure for forensic investigation.[2]

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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 orofacial tissue is of monumental value to the physical anthropologist due to its applications

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in forensic identification.[4] Arch width may provide insignificant feature differences among and within a population but form a stronger data for identification purposes.

Traditionally, 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[5-9] and deciduous crowns[10-16] using diagnostic dental casts, but only few studies are conducted using the arch width as parameters which were in permanent dentition.[17-20]

This study emphasizes the importance of arch width in sexual dimorphism for the following reasons: (1) the pelvis, which is the most precise structural indicator, maybe 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.[21]

If sexual dimorphism in deciduous dentition is proved for its significance in sex determination like permanent dentition,[5-9] then it could be useful to precisely identify the sex of the children. Deciduous dentition-based studies have been carried out by Black,[22] De Vito and Saunders[23] and Zadzińska *et al*.,[24] they have published a series of discriminant functions for sex determination, but they have taken odontometric into consideration. 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 with arch width as parameters.

The magnitude and pattern of sexual dimorphism in the size of jaw differ from one population to another. Hence, there is a need for finding out differences in the arch width 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.[22-27] However, the present study considered only the maxillary intercanine width (Max 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 by using maxillary arch width in children of Namakkal district from South Indian origin.

MATERIALS AND METHODS

Study design

The study was a cross-sectional study conducted for a period of 3 months.

Sample selection

The study sample consisted of 364 children who were selected from 940 children aged between 4 and 6 years of South Indian origin by cluster random sampling method. The clusters were government elementary schools in Namakkal district. 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, occlusion with flush terminal plane and participants with full complement of deciduous dentition were only considered. The study was approved by the Institutional Ethical Committee, JKK Natarajah Dental College and Hospital, Namakkal district, Tamil Nadu, India.

Procedures and parameters

Alginate impressions (Tropicalgin, Zhermack Clinical, New Jersey, USA) of the upper 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 0.01 mm (Mitutoyo Absolute Digimatic Sliding Caliper, Tokyo, Japan, 0.05-mm resolution) was used for obtaining the measurements.

The arch width at canine, first molar and second molar of maxilla was considered for analysis [Figure 1]. All measurements were recorded by one of the investigators and calibration was done by the senior author. A total of three parameters were used as a predictor variable.

The three variables included were Max ICW which is the distance between the cusp tips of canine [Figure 2], maxillary intermolar width at first molar which is the distance between the central fossa of first molars [Figure 3] and maxillary intermolar width at second molar which is the distance between the central fossa of second molars [Figure 4].

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 were 0.953 (95% confidence interval: 0.914–0.992),

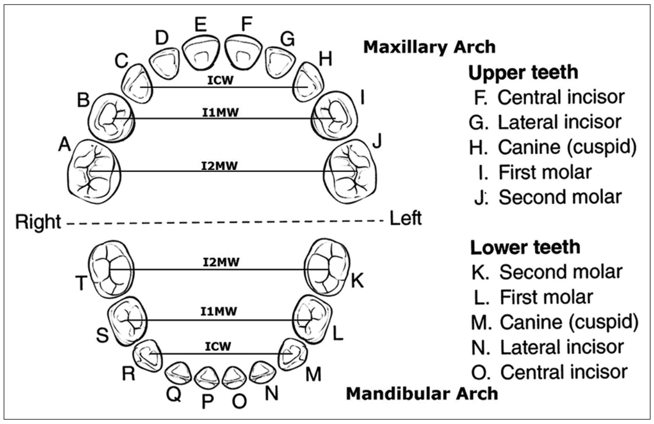

Figure 1: Line diagram showing the maxillary arch with different variables and measuring methods

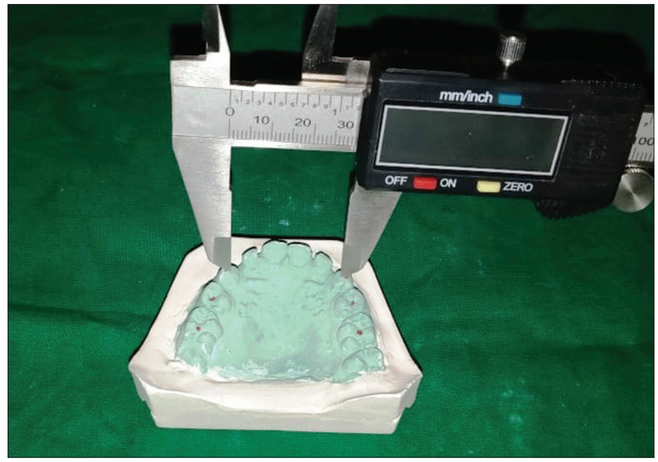

Figure 2: Measuring method for intercanine width of maxillary arch

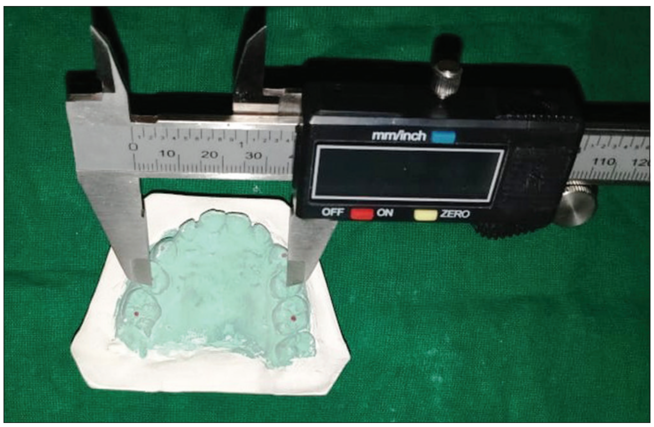

Figure 3: Measuring method for interfirst molar width of maxillary arch

Figure 4: Measuring method for intersecond molar width of maxillary arch

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 Sciences (SPSS) Version 20.0 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 step-wise discriminant function analysis, which has the potential to optimally separate the sexes; further the statistical significance was assessed using Wilks' lambda. The variables having the higher discriminant function coefficient were included in the discriminant function for developing the formula.

$$DFS = C + df_1x_1 + df_2x_2 + ... + df_nx_n$$

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 0.953. Hence, the measurements made at two different points showed 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 for all parameters. The different predictor variables of arch width selected between male and females were subjected to Student's *t*-test, and the level of significance was $P < 0.05$. Statistically significant difference was found among Max ICW [Table 1].

Further, the parameters included in the functional analysis were checked for step-wise entry for the tests of equality of group means for its significance, and it was also found

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

Jaw transverse measurement	Variable	Male	Female	*t*-test	Significant
Maxilla	ICW	29.08±2.07	28.31±1.91	1.735	0.006*
	I1MW	34.12±2.36	33.95±2.50	0.129	0.516
	I2MW	39.97±2.18	39.83±2.11	1.289	0.614

*Significant. ICW: Intercanine width, I1MW: Intermolar width at first molar, I2MW: Intermolar width at second molar

that they were statistically significant with $P < 0.05$ for the Max ICW [Table 2]. The overall Wilk's Lamda for all the predictor variables was calculated, and it showed a very high statistically significant value among the parameters with $P < 0.05$ [Table 3].

Table 4 shows the conical discriminant function coefficient values for the predictor variables which entered the functional analysis by Wilk's Lamda.

The discriminant analysis produced the best discriminant functions, and all the predictor variables were included in the functions 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 3].

The best discriminant function was

$$\text{DFS} = -5.274 + 0.732\,(\text{Max. ICW}) - (\text{Max. I1MW}) - 0.244\ \ (\text{Max. I2MW})$$

Expansion of abbreviation:−

DFS: Discriminant function score

Man. I1MW: Mandibular first intermolar width

Max. ICW: Maxillary intercanine width

From the step-wise discriminant analysis, the group centroid was also generated for both the sexes. A group centroid is the mean discriminant score for each sex. A cutoff 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 cutoff point between the sexes was −0.0385. The male group centroid was 0.208 and the female group centroid was −0.285 [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

Table 2: Tests of equality of group means

	Wilks' Lambda	*F*	df1	df2	Significant
Max ICW	0.965	7.762	1	214	0.003
Max I1MW	0.998	0.423	1	214	0.386
Max I2MW	0.999	0.214	1	214	0.734

Max ICW: Maxillary intercanine width, Max I1MW: Maxillary intermolar width at first molar, Max I2MW: Maxillary intermolar width at second molar

Table 3: Overall Wilk's Lambda to test the significance among the predictor variables

Test of function(s)	Wilks' Lambda	χ^2	df	Significant
1	0.944	12.332	3	0.006**

**Highly significant

Table 4: Conical discriminant function coefficient of the entered predictor variables

Entered variables	Function 1
Max ICW	0.732
Max I1MW	−0.177
Max I2MW	−0.244
Constant	−5.274

Max ICW: Maxillary intercanine width, Max I1MW: Maxillary intermolar width at first molar, Max I2MW: Maxillary intermolar width at second molar

Table 5: Group centroid for both the sex using unstandardized canonical discriminant functions

Sex	Function 1
Male	0.208
Female	−0.285

Table 6: 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	115	11	126
	Female	18	73	91
Percentage	Male	91.3	8.7	100.0
	Female	19.8	80.2	100.0
Cross-validated[b]				
Count	Male	113	13	126
	Female	21	70	91
Percentage	Male	89.7	10.3	100.0
	Female	23	77	100.0

[a]85.75% 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]83.35% of cross-validated grouped cases correctly classified

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 6].

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 6. Hence, the original grouped cases correctly classified were 85.75%.

DISCUSSION

Sexual dimorphism in the arch width 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 arch width parameter of deciduous dentition in specific populations, even within the same population in the historical and evolutional perspective, it is necessary to determine precise population values in order to make identification possible on the basis of dental measurements. These values can be of use as an adjunct in determining sex in specific cases: in individuals as well as in groups (mass disasters, archeological sites, etc.,).[26]

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, arch width of deciduous dentition can be used in determining the sex after the tooth has erupted even in child skeletons or samples whose skeletal features are not defined.

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 intra-arch measurements in particular. This is a maiden study in using the maxillary intra-arch measurements in deciduous dentition for sex determination using discriminant function analysis.

In the present study, it has been identified that significant sex differences exist in arch width parameter in the upper jaw. It was also found that these differences were large enough to determine the sex with classification accuracy between 89.7% and 77% 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, the equation developed by this study ranges in accuracy from 89.7% and 77%. This cannot be directly compared for sex determination among pediatric population because no study is conducted using arch width using discriminant function analysis. This was considerably higher when compared to that developed by Black,[22] De Vito and Saunders[23] and Zadzińska *et al*.[24] with 33.3%–75%, 35.7%–45.9% and 38.5%–73.3%, respectively, and similar to the study conducted by Shankar *et al*.,[25] but all these studies used odontometric parameters for sex determination.

This shows that the present study provides robust evidence to identify the sex in a pediatric population using its formula. Such population variations may result from differences in the quality of environment during growth and development, particularly maternal health, which may influence tooth size.

CONCLUSION

The present study elicits the fact that the level of sexual dimorphism in deciduous maxillary arch width dimensions of an Indian population is sufficiently large enough for determining sex to an accuracy of 89.7% and 77% 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 arch width values in the function and referring it to the cutoff point which discriminates the sex.

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Conflicts of interest

There are no conflicts of interest.

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