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Sex Estimation by Odontometric Study of the Maxillary Canine Teeth using Discriminant Function Analysis

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Abstract

Sex estimation till date remains an importance if not the first step in any forensic investigation. The present study thus seeks to evaluate sexual dimorphism and estimate sex from the maxillary canine teeth of the University of Port-Harcourt Students. The study was carried out at the dental clinic of the University of Port Harcourt teaching hospital. A total of hundred (100) volunteer student subjects comprising 50 Males (M) and 50 Females (F) were involved in the study. An impression of upper jaw was made using alginate impression material and casts were prepared using dental stone. A 150mm digital venier caliper with 0.001mm accuracy was used to measure the following six (6) parameters [inter-canine width (ICW), Inter-premolar width (IPMW), Inter-molar width (IMW), Left and right maxillary width (LCCW, RCCW) and Maxillary depth (MD)]. Analysis was done using t-test and discriminant function analysis. The mean ICW (M = 41.70 ± 3.22 mm, F = 40.72 ± 2.64 mm), IMW (M = 60.432 ± 0.86 mm, F = 59.62 ± 0.38 mm) and MD (M = 20.875 ± 0.55 mm, F = 20.192 ± 0.36 mm) of males were statistically insignificant at $P < 0.05$ when compared to that of the females. However, the LCCW (M = 7.857 ± 0.07 mm, F = 7.417 ± 0.07 mm) and RCCW (M = 7.863 ± 0.07, F = 7.521 ± 0.06mm) as well as the IPMW (M = 55.113 ± 0.36mm, F = 53.098 ± 0.41 mm) statistically significant at $P < 0.05$, hence sexually dimorphic. A discriminant function equation [Sex = -19.533 + -0.096 (ICW) + 0.242 (IPMW) + -0.063 (IMW) + -0.029 (MD) + 1.197 (LCCW) + 0.731 (RCCW)] was derived for sex estimation with values tending towards -0.549 suggesting that the unknown individual is likely a female, while values tending towards 0.549 suggests a male. The findings made in the present study will however, play a substantive role in forensic investigation especially in the University of Port Harcourt.

Keywords: Maxillary canine; Sexual dimorphism; Discriminant function analysis and sex estimation

Introduction

Human identification is one of the most daunting challenges that man has been confronted with over time. Sex estimation is actually one of the most useful procedures in determining the biological profile of a yet to be identified human remains, since a correct result would automatically exclude about half the population in search operations [1]. Concerning sex estimation from human remains, many anatomical structures have been used, but the teeth appears to be the most reliable method, since the teeth is the most durable (have the ability to withstand post mortem events for a long period of time) and resilient part of the skeleton. Sex can therefore be estimated by comparing the dental features (tooth dimensions).

Teeth are known to be unique organs made of the most enduring mineralized tissues in the human body, as such, they have an extraordinary resistance to putrefaction and the effects of external agents (physical, thermal, mechanical, chemical or biological) which makes them invaluable elements for anthropological, genetic, odontologic, evolutionary and forensic investigations [2]. Embryologically, it appears when embryonic cells grow and erupt into the mouth. The teeth are held within the jaw bones and therefore serve several important functions aside chewing [3].

Tooth extraction is the most frequently performed dental procedure. However, the maxillary as well as mandibular canines among other teeth are the least extracted being less affected by periodontal diseases [2].

It is therefore likely to remain intact even when a larger percentage of other teeth are already extracted, which explains why it was chosen for this study.

A number of authors have carried out studies to estimate sex using odontometric parameters. Madhavi et al. [4]; Staka and Bimbashi [5]; Nick et al. [6]; Abdol et al. [7] and Rahul et al. [8]; found the maxillary canine width (mesio-distal dimension) as a tool for sex determination, while Shalini et al. [9]; Gupta et al. [10] and Parekh et al [2] also observed this difference in inter-canine width. Mohammed et al [11] also found the mesio-distal width of the maxillary canines, inter-canine width and standard maxillary canine index to be higher in males and also useful in sex estimation. Ayeesha et al. [12] found ethnic difference in maxillary and mandibular canine width in South Indian and Central Indian populations.

While Sherfudhin et al. [13] and Srivastava [14] recorded significance difference in lower (mandibular) canines.

Therefore, the study was carried out to estimate sex using some odontometric parameters from the maxillary canine of University of Port Harcourt Students.

Materials and Methods

The study involved 100 volunteer subjects (50 males and 50 females aged 17 to 30 years) who were all students of the University of Port Harcourt, Choba, Rivers State, Nigeria. Ethical clearance was obtained from the Research Ethics Committee of the College of Health Sciences,

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University of Port Harcourt. The subjects were recruited following specific criteria. They were informed of the nature of the study and procedure involved, and only those who gave their consent participated in the study. A multistage stratified sampling technique was adopted and sample size determined using Cochran [15].

Inclusive criteria

The following were considered before selecting subjects:

1. The teeth were without any tooth agenesis, trauma or any anomalous shape.

2. All permanent teeth from the central incisors to the first molars in all 4 quadrants must be presents.

3. Must be 18 years and above.

4. There was no evidence of bubbles or fracture or caries.

5. There were no congenital abnormalities of the palate and lips (e.g. cleft palate).

Exclusive criteria

The following criteria lead to the exclusion of some volunteers:

1. Subjects with history of orthognathic surgery and orthodontic treatment.

2. Subjects with partial dentures as well as braces were excluded.

3. Subjects who are allergic to the impression material used.

Procedure

Subjects who met the criteria were made to sit upright on a dental chair, alginate paste prepared (using alginate, Type 4 dental stone, 0.051% hydrochloric acid, spatula and mixing bowl) was loaded in a perforated impression tray. The tray was placed in the subject's mouth to obtain tooth impressions, which was removed after about 80 to 100 seconds, casted using dental stone mixed with water and left to solidify (Figure 1). This was later de-casted separating the now solidified dental stone from the solid alignate powder mixture (now dental cast) on the impression tray. The dried dental cast with tooth impressions was measured following Shalini et al. [9] (Figure 2). The following measurements were taken (using 150mm digital Vernier caliper calibrated to 0.001mm) which includes: Inter-canine width (ICW), Inter-premolar width (IPMW), Inter-molar width (IMW), Left and right maxillary width (LCCW, RCCW) and Maxillary depth (MD) (Figure 3).

Figure 1: Diagram showing palatal imprints of the subjects.

Figure 2: Dried dental cast with impression.

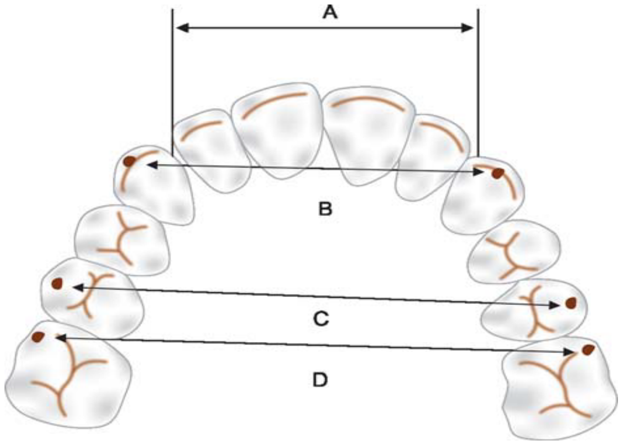

Figure 3: Arch width measurements: A - Interincisor width; B -Intercanine width; C - interpremolar width; D - intermolar width.

Inter-canine width (ICW) was measured as the distance between the tip of the two canine teeth in a straight line.

Inter-premolar width (IPMW) measured as the distance between the tip of the two 2nd maxillary premolars in a straight line.

Inter-molar width (IMW) measured as the distance from the buccal groove on the occlusal surface along the buccal margin of the first molar to the contra lateral tooth.

Left and Right maxillary width (LCCW, RCCW) was taken to be the distance between the crowns of each canine tooth along the buccal surface.

Whereas the Maxillary depth (MD) represents the length of the line perpendicular to the midpoint of a line drawn along the distal margins of the first premolars.

Data Analysis

The data obtained were analyzed using Statistical Package for the Social Science (SPSS IBM version 23). Descriptive statistics (Mean ± SD, SE) was done to establish cutoffs, Independent sample T-test guided by Levene's test for Equality of Variances was carried to establish sexual dimorphism (Table 1), while Discriminant Function Analysis (DFA) was carried out to derive a discriminant regression equation for sex estimation. Confidence interval was set at 95%, hence P < 0.05 was considered significant.

Results

The data analyzed in this section was obtained from 100 subjects (50 males and 50 females), with a mean age of 22.27 ± 3.0 years old (17 to 30 years). Result was presented in Tables 1-7; Descriptive statistics and test of mean difference (Independent sample T-test) was presented in Table 1, while discriminant function analysis (DFA) for sex estimation was presented in Tables 2-7.

Descriptive and inferential statistics

The result showed that the males have higher mean values in all the measured parameters [Intercanine Width (ICW), Interpremolar Width (IPMW), Intermolar Width (IMW), Maxillary Depth (MD), Left Canine Crown Width (LCCW), Right Canine Crown Width (RCCW)] compared to the females. ICW (M = 41.698 ± 0.45mm; F = 40.719 ±0.37 mm), IPMW (M = 55.113 ± 0.36 mm; F = 53.098 ± 0.41 mm), IMW (M = 60.432 ± 0.86 mm; F = 59.620 ± 0.38 mm), MD (M = 20.875 ± 0.55 mm; F = 20.192 ± 0.36 mm), LCCW (M = 7.857 ± 0.07 mm; F = 7.417 ± 0.07 mm), RCCW (M = 7.863 ± 0.07 mm; F = 7.521 ± 0.06 mm). Differences in Mean values between male and female subjects were statistically insignificant at P < 0.05 except for IPMW (t = 3.703, P < 0.001), LCCW (t = 4.644, P < 0.001) and RCCW (t = 3.655, P < 0.001).

Discriminant function analysis

Discriminant Function Analysis (DFA) is the best statistical model in sex determination and therefore was chosen for this study. Six (6)

Parameters	SEX	Mean ± S.D	S.D	df	t-test for Equality of Means				
					Mean Dif. (I-J)	Std. Error Dif	t-value (cal)	P-value (cal)	Inference
Intercanine width (mm)	Male	41.698 ± 0.4	3.22	98	0.979	0.589	1.663	0.099	Not Sig
	Female	40.719 ± 0.37	2.64						
	Total	**41.208 ± 0.30**	**2.97**						
Interpremolar width (mm)	Male	55.113 ± 0.36	2.52	98	2.015**	0.544	3.703	<0.001	Sig
	Female	53.098 ± 0.41	2.91						
	Total	**54.105 ± 0.41**	**2.89**						
Intermolar width (mm)	Male	60.432 ± 0.86	6.09	98	0.812	0.94	0.864	0.39	Not Sig
	Female	59.62 ± 0.38	2.66						
	Total	**60.026 ± 0.47**	**4.7**						
Maxillary depth (mm)	Male	20.875 ± 0.55	3.86	98	0.682	0.652	1.046	0.298	Not Sig
	Female	20.192 ± 0.36	2.53						
	Total	**20.534 ± 0.33**	**3.26**						
Left Canine Crown Width (mm)	Male	7.857 ± 0.07	0.47	98	0.440**	0.095	4.644	<0.001	Sig
	Female	7.417 ± 0.07	0.48						
	Total	**7.637 ± 0.05**	**0.52**						
Right Canine Crown Width (mm)	Male	7.863 ± 0.07	0.5	98	0.342**	0.094	3.655	<0.001	Sig
	Female	7.521 ± 0.06	0.43						
	Total	**7.692 ± 0.05**	**0.5**						

***S.E** = Standard Error, **S.D** = Standard Deviation, **df** = degree of freedom*

Table 1: Descriptive statistics and Independent sample t-test of the measured variables between sex.

Parameters	Wilks' Lambda	F	df1	df2	P-value	Inference
Intercanine width (mm)	0.973	2.767	1	98	0.099	Not Significant
Interpremolar Width (mm)	0.877	13.711	1	98	<0.001	Significant
Intermolar Width (mm)	0.992	0.746	1	98	0.39	Not Significant
Maxillary Depth (mm)	0.989	1.094	1	98	0.298	Not Significant
Left canine crown Width (mm)	0.82	21.564	1	98	<0.001	Significant
Right canine crown Width (mm)	0.88	13.361	1	98	<0.001	Significant

Table 2: Tests of Equality of Group Means.

Box's M equality in covariance		**EIGEN VALUES**		
		Function	Eigen value	Canonical Correlation
Box's M	123.57	1	0.308	0.485
F				
Approximately	5.499			
df1	21			
df2	35,323.50			
P-value	<0.001			

Table 3: Tests of Equality in population covariance matrices and canonical correlation.

Test of Function(s)	Wilks' Lambda	Chi-square	df	P-value	Inference
1	0.764	25.514	6	<0.0001	Significant

Table 4: Wilks' Lambda test for predictability into group membership.

Box's M structure Matrix Coefficients		Standardized Canonical Discriminant Function Coefficients	Unstandardized canonical discriminant function coefficients
Variables (mm)	**Function [a]**	**Function**	**Function [b]**
Constant			-19.533
Intercanine width (mm)	0.3034	-0.281	-0.096
Interpremolar width (mm)	0.6742	0.657	0.242
Intermolar width (mm)	0.1576	-0.296	-0.063
Maxillary depth (mm)	0.1905	-0.094	-0.029
Left canine crown width (mm)	0.8451	0.567	1.197
Right canine crown width (mm)	0.6653	0.342	0.731

Function a = Pooled within-groups correlation between discriminating variables and standardized canonical discriminant functions
Function b = Coefficients used for computing group membership values
Order of strength of predictability = 1, 2, 3, 4, 5, 6

Table 5: Canonical discriminant function coefficient structured, standardized and unstandardized.

Sex	Function
Male	0.549
Female	-0.549

[a]Unstandardized canonical discriminant functions evaluated at group means.

Table 6: Functions at group centroids.

Sex			Predicted Group Membership		Total
			Male	**Female**	
Original[a]	Count (%)	Male	37 (74.0)	13 (26.0)	50 (100)
		Female	11 (22.0)	39 (78.0)	50 (100)
Cross-validated[b]	Count (%)	Male	35 (70.0)	15 (30.0)	50 (100)
		Female	14 (28.0)	36 (72.0)	50 (100)

a. 76.0% of original grouped cases correctly classified.

b. 71.0% of cross-validated grouped cases correctly classified.

Table 7: Percentage predictability for group membership.

parameters were involved in the DFA. Test of equality of mean difference for male and female parameters revealed that three (3) out of the six (6) predictors entered into the model were significant ($P < 0.001$).

The box's M covariance matrix (Table 3) shows equality in the group variance, hence meeting the assumption of equal group variance which indicates a limited discrepancy in the predictor variables and magnitude of the actual effect of the predictors (canonical coefficient) and the outcome is the square of the coefficient $(0.485)^2$; this indicates that the relationship between the predictor variable and the outcome is 0.24. Hence the predictor variables (ICW, IPMW, IMW, MD, LCCW and RCCW) will make predictions that are statistically significant in their outcomes (Wilk's Lambda = 0.764, $P < 0.0001$, $x^2 = 25.51$) (Table 4).

The unstandardized coefficients (Table 5) were used to generate the discriminant function equation, with the coefficients expressing each individual variables contribution to the discriminant function equation; hence Sex = - 19.533 + -0.096 (ICW) + 0.242 (IPMW) + -0.063 (IMW) + -0.029 (MD) + 1.197 (LCCW) + 0.731 (RCCW).

However, using the equation above, the sex of an unknown individual can be estimated or determined. Bearing the adjusted canonical centroids (-0.549 to 0.549) in mind, if the product obtained is close to -0.549, the proposed sex is likely a female, but if it is rather close to 0.549, then it is likely going to be a male.

When this model was tested with the data obtained in the present study, an 'F' likelihood ratio with model accuracy of 71.0% was obtained. Prediction using this model was found to be statistically significant ($P < 0.01$); 71.0% predictability into group membership, which seems strong enough with an almost equal prediction for males (72.0%) and females (70.0%).

Hence with this result it can then be concluded that a good prediction into group membership can be made using this model.

Discussion

One of the preliminary steps taken in any attempt to identify a missing individual from skeletal remains (e.g. teeth) is first to identify the sex. The correct prediction of the sex simplifies the identification process as only one sex (the sex of the missing individual) need to be considered [16].

From the present study, the canine width of males was found to be higher than those of the females, although the difference was not statistically significant. According to Staka and Bimbashi [5], it is an established fact that males have larger teeth compared to females. Also Gupta et al. [10] reported that a statistically significant difference between the inter-canine width of males and females. However other authors such as Eboh and Etetafia [17] differ in their findings, stating that the ability to determine sex using maxillary canine is poor.

Left and right canine crown widths were significantly greater in males compared to the females. This is in agreement with the findings of Iscan and Kedici [18], who reported that statistically significant difference exist between the right and left maxillary canines. Acharya and Sivapathasundharam [19] also reported that sexual dimorphism bilaterally exists in maxillary canines. Various theories have been postulated to explain canine dimorphism. One of such theories explained that canine dimorphism results from the greater thickness of enamel in males which is as a result of the long period of amylogenesis (for both temporary and permanent dentitions) compared to females [5], while Nayak et al [20] explained this to be as a result of the Y chromosome producing slower maturation.

As observed in the present study, difference in inter-molar width between males and females was not significant, a position that Iscan and Kedici [18] failed to support, who rather reported that the maxillary inter-molar width had both high specificity and t-value and as such may be useful in precise gender estimation.

The inter-premolar width showed statistical significance in both sex; an observation which is in line with the findings made by Hasim and Al-Ghamdi [21] whose worked on British gender variations in inter-premolar with and found it to be useful in sex estimation in their study population. On the other hand, Eboh and Etetafia [17] reported that the inter-premolar width is not a reliable parameter for estimating sex. Conversely Hasim and Al-Ghamdi [21] categorically stated that the canines were the only teeth to exhibit sexual dimorphism, but the present study had shown that the inter-premolar width can also be used in sex estimation.

In the present study, the maxillary depth showed no statistical significance in males and females. Although a study done by Abdol et al. [7] also reported that maxillary depth showed statistical significance in sex estimating to 10 years of age.

However, an interplay between genetic and environmental factors could be responsible for the variations observed in the magnitude of sexual dimorphism [5]. Hence different human population (including ethnic groups) may show a varying degree of sexual dimorphism [18].

Conclusion

The present study has established that the maxillary canines and inter-premolar width is useful in estimating sex. They can be used as adjunct alongside other standard procedures for sex estimation, especially when fragmentary remains are encountered in mass disaster and in other similar situations. Thus the study will therefore find its relevance in anthropology as well as forensic science in sex estimation.

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