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Research Article

Determination of Sexual Dimorphism by Odontometric Study Using Discriminant Function Analysis of Adult Ikwerre Dental Cast

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Abstract: Sex determination with the aid of skeletal still remains a problem to forensic experts particularly when parts of the body are mutilated or decomposed; thus, to limit this difficulty various techniques are on trial for accuracy. The aim of the study is to investigate the existence of sexual dimorphism in the Ikwerres ethnic group of Nigeria by simple odontometric analysis of dental cast. A total of 297 normal dental cast of adult subjects consisting of 147 males and 150 females between ages 20-45 years of Ikwerre descent were used for the study. Seven (7) arch dimensions were measured using a 150mm digital vernier caliper calibrated to 0.00mm and the arch index calculated. Sex difference were tested using unpaired t-test, and discriminant function analysis (DFA) developed using SPSS version 20.The present study showed that the males displayed higher mean values than the females in all measured parameters; this observed difference was significant for MM1 (t=2.405, P=0.018) and PM1 (t=2.359, P=0.02) but not for other five variables (AC1, PC1, CC1, TPL and TPD; p>0.05). The DFA for group membership prediction model when tested with the present data derived a significant 'F' likelihood ratio test (P=0.009), a Wilks' Lambda predictability value of 0.866 having a model accuracy of 63.9% with a better prediction for female (68%) than males (59.6%).Arch dimensions are not static as they change systematically during the period of intensive growth and development (age variability)..Although discriminant function analysis successfully predicted 64% of data into groups (sex) and the prediction statistically significant; however a 63.9% predictability into group membership seems quite low. This indicates that the use of odontomery alone may not be effective for sex differentiation.
Keywords: Ikwerre, Discriminant Function Analysis, Odontometric Analysis, Sexual dimorphism, Arch dimensions

INTRODUCTION

Sex determination with the aid of skeletal still remains a problem to forensic experts particularly when parts of the body aremutilated, charredor decomposed; thus, to limit this difficulty there have been investigation into the use of odontology and palatalrugology (dental arch dimensions, rugae shape & length and dentitions) to establish sexual, ethnic and racial difference. These techniques have been on trial for accuracy in classification.

Forensic odontology is the study of dental applications in legal proceedings [1]. The subject covers a wide variety of topics including individual identification, mass identification, comparative differentiation and bite mark analysis [1,2].

Dental arch dimensions are not static and change systematically during the period of intensive growth and development[3]. The study of human odontometric trends relies upon repeated measurements of tooth size,[4] rugae[5] and arch dimensionsin a given population. Whilst short term trends may be evidenced by measurements taken on samples a human generation apart, the identification of long term trends will involve samples separated by thousands, or even millions of years[4]. Odontometricstudy of the variation in the dental arch dimensions can be used in age and sex determination as it helps in the recovery of antemortem records for comparison and establishment of identity[6]. Information concerning maxillary dental arch dimensions in human populations is of great value to clinicians in different fields of dentistry (orthodontics, pedodontics, prosthodontics and oral surgery) and it is of immense importance to anthropologists to study the growth and development of the dental arch for different population[6,7].

Many factors such as heredity, growth of the bone, eruption and inclination of the teeth, external influences, function, and ethnic background could affect the size and shape of the dental arches[8]. Dental casts are considered a vital diagnostic tool in orthodontic practice because they facilitate the analysis of tooth size and shape; alignment and rotations of the teeth, arch width, arch length, arch form and symmetry[9].

The basic theory and principles of discriminant analysis was established by Fisher[10,11,12]. Discriminant classifiers represents combination of attributes using '*and*' operators (weighted by respective coefficients; these methods represent '*or*' combinations by allowing interaction[13]. This technique is designed to generate directions for classifying individuals into a defined group on the basis of a set of measurements of the individual[14]. In this study this technique was used for sex grouping.

MATERIALS AND METHOD

A total of 297 healthy adult subjects consisting of 147 (49%)males and 150 (51%) females between in age between 20-40years of Ikwerre origin were used for the study. Interviewer's non-questionnaire method was used to ascertain the ethnicity, family history and dental health status of the subjects. The subjects were selected based on specific criteria and they were informed of the procedure and nature of the study and only those who gave their consent participated in the study. The subjects were recruited from University of Port Harcourt students and residents of Alakahia community, Rivers State.

Inclusive Criteria

The following were the criteria for selection and participation in this study:
Volunteers without orthodontic treatment and those with 28-32 permanent teeth were selected.
All volunteers were healthy, free of congenital abnormalities and palatal defects.
All of Ikwerre descent traced to the grandparents.

Exclusive Criteria

The following criteria lead to the exclusion of some volunteers:
Those that had previously undergone orthognathic surgery and orthodontic treatment.
Volunteers who are allergic to impression material.
Volunteers wearing partial dentures and braces were excluded.

Dental cast modelling and Measurement

The maxillary dental cast of the subjects were prepared using alginate, perforated plastic or maxillary impression trays, mixing bowl, spatula, water, Type 4 dental stone, and 0.051% hydrochloric acid. The alginate impressions of the maxillary dentition was made and poured with dental stone. A dental plaster base was made and casts were preserved for measurement.

The formed alginate impression were measured using a 150mm digital vernier caliper calibrated to 0.00mm;Improvisation for measurement of the arch length was carried out with the use of a flexible broom-stick and rubber-band. The following arch dimensions were measured in line with previous studies by Hassanali and Odhiambo[15] and later Mohammad *et al.*[16]:

Inter-Molar Distance (MM1): The distance measured from the buccal groove on the occlusal surface along the buccal margin of the first permanent molar to the contra lateral tooth.

Inter-Canine Distance (CC1): From the tip of the cusp of canines across the arch.

Inter-Premolar Distance (PM1): The distance measured from the buccal groove on the occlusal surface along the buccal margin of the first premolar to the contra lateral tooth.

Anterior Arch Circumferences (AC1): From the point of maximum convexity of canine in the middle third of the buccal surface along the anterior teeth to the similar point on the canine on the opposite side of the arch.

Posterior Arch Circumferences (PC1): From the maximum convexity on the buccal groove of the first permanent molars along the middle third of the teeth in the arch to the same point on the opposite side.

Total Palatal Length (TPL): From the center of palatal incisal papilla to the point on a horizontal line drawn along the distal margins of the first permanent molars.

Total Palatal Depth (TPD): A perpendicular to the midpoint of a line drawn along the distal margins of the first permanent molar.

Arch index (AI1): Calculated by dividing the Inter-molar distance (MM1) by the Total palatal length (TPL).

Statistical Analysis

SPSS (Statistical package for social Sciences version 20) ANOVA and Unpaired *t* test was used in assessing the sex differences in the measured arch dimensions and univariate discriminant function analysis was used to ascertain the possibility of classifying the sexes into group membership based on the observed variables. Only statistically significant or close to significant variables were selected for the discriminant function analysis.

RESULTS

The means and standard deviations (M ± SD) of the maxillary dental arch measurements are shown in Table 1. The standard error of mean (S.E), group median, minimum and maximum values were recorded and expressed by the range.

Male and female comparison

The males displayed greater mean values than the females; the mean±S.E of male AC1, was found to be 48.47±0.644mm, while female was 47.202±0.682mm

with a mean difference of 1.276±1.358mm. The mean±S.E of male PC1 was found to be 100.473±0.902mm while female was 98.471±0.979mm with a mean difference of 2.002±1.499mm. The mean±S.E of male MM1 was found to be 50.627±0.605mm while female was 48.772±0.479mm with a mean difference of 1.855±2.42mm. The mean±S.E of male CC1 was found to be 35.355±0.534mm while female was 34.725±0.452mm with a mean difference of 0.629±0.903mm; mean±S.E of male PM1 was found to be 39.006±0.463mm while female was 37.535±0.418mm with a mean difference of 1.470±2.364mm. The mean±S.E of male TPL was found to be 28.881±0.466mm while female was 27.559±0.485mm with a mean difference of 1.322±1.960mm; mean±S.E of male TPD was found to be 18.853±0.453mm while female was 17.760±0.368mm with a mean difference of 1.092±1.882mm (Table 1).

The ANOVA and t-testfor difference in mean indicated a significant effect sex of MM1 [t=2.405, P=0.018] and PM1 [t=2.359, P=0.02] but no significant difference was observed forAC1, PC1, CC1, TPL and TPD between the sexes (Table 2).

Discriminant Function Analysis

Table 4 shows the level of difference in the observed values of males and females with $p<0.05$ indicating a statistically significant difference. The Box's M covariance matrix showed equality in the group variance, hence meeting the assumption of equal group variance which indicates a limited discrepancy in the predictor variables. The magnitude of the actual effect of the predictors (canonical coefficient) and the outcome is the square of the coefficient $(0.367)^2$; this indicates the relationship between the predictor variable and the prediction outcome is 0.13. The group of predictor variables (MM1, PM1, TPL and TPD) will make predictions that are statistically significant in their outcomes (Wilk's Lambda = 0.866, P=0.009) (Table 5), as the variables that seems to have the highest predictorcapability which can be used for predictions of group membership are PM1 (0.63), MM1 (0.615), TPL (0.51) with low value for TPD (0.49)(Table 6).

Table-1: Descriptive characteristics of the measured arch dimensions

PARAMETERS	SEX	MEAN (S.D)	STD. ERROR OF MEAN	GROUPED MEDIAN	RANGE (MIN –MAX)
AC1 (mm)	**Male**	48.479 (4.41)	0.644	48.58	39.47 - 57.3
	Female	47.202 (4.82)	0.682	47.35	38.93 - 61.65
	Total	**47.821 (4.65)**	**0.472**	**47.82**	**38.93 - 61.65**
PC1 (mm)	**Male**	100.473 (6.18)	0.902	100.7	87.82 - 116.06
	Female	98.471 (6.92)	0.979	97.2	88.24 - 124.87
	Total	**99.441 (6.62)**	**0.672**	**99.39**	**87.82 - 124.87**
MM1 (mm)	**Male**	50.627 (4.15)	0.605	50.59	42.63 - 69.85
	Female	48.772 (3.38)	0.479	49.1	38.92 - 55.31
	Total	**49.671 (3.87)**	**0.393**	**49.32**	**38.92 - 69.85**
CC1 (mm)	**Male**	35.355 (3.66)	0.534	36	27.58 - 43.15
	Female	34.725 (3.20)	0.452	34.645	26.90 - 42.56
	Total	**35.03 (3.43)**	**0.348**	**35.32**	**26.90 - 43.15**
PM1 (mm)	**Male**	39.006 (3.17)	0.463	39.45	29.44 - 44.47
	Female	37.535 (2.95)	0.418	37.245	28.25 - 43.61
	Total	**38.248 (3.13)**	**0.318**	**38.37**	**28.25 - 44.47**
TPL (mm)	**Male**	28.881 (3.19)	0.466	28.93	18.8 - 36.75
	Female	27.559 (3.43)	0.485	28.09	17.98 - 34.56
	Total	**28.199 (3.37)**	**0.342**	**28.63**	**17.98 - 36.75**
TPD (mm)	**Male**	18.853 (3.11)	0.453	18.8	13.07 - 28.31
	Female	17.76 (2.60)	0.368	18.265	11.39 - 22.12
	Total	**18.29 (2.89)**	**0.294**	**18.46**	**11.39 - 28.31**
ARCH INDEX (AI1)	**Male**	1.772 (0.23)	0.033	1.708	1.24 - 2.50
	Female	1.802 (0.31)	0.043	1.747	1.33 - 2.91
	Total	**1.788 (0.27)**	**0.027**	**1.724**	**1.24 - 2.91**

Table-2: Analysis of variance and mean difference between males and females

		ANOVA		T-Test			Inference
		Group median	**F-value, P-value**	**Mean Difference**	**Std. Error Difference**	**t-value, p-value**	
AC1 * SEX (mm)	**Male**	48.58	F=1.843, P=0.178	1.276	0.937	t=1.361, P=0.177	ANOVA (Not Sig), T-test (Not Sig)
	Female	47.35					
PC1 * SEX (mm)	**Male**	100.70	F=2.246, P=0.137	2.002	1.331	t=1.504, P=0.136	ANOVA (Not Sig), T-test (Not Sig)
	Female	97.20					
MM1 * SEX (mm)	**Male**	50.59	**F=5.858, P=0.017***	1.855	0.771	**t=2.405, P=0.018***	**ANOVA (Sig), T-test (Sig)**
	Female	49.10					
CC1 * SEX (mm)	**Male**	36.00	F=0.816, 0.369	0.629	0.700	t=0.90, P=0.371	ANOVA (Not Sig), T-test (Not Sig)
	Female	34.65					
PM1 * SEX (mm)	**Male**	39.45	**F=5.589, P=0.02***	1.470	0.623	**t=2.359, P=0.02***	ANOVA (Sig), T-test (Sig)
	Female	37.25					
TPL * SEX (mm)	**Male**	28.93	F=3.843, P=0.053	1.322	0.673	t=1.965, P=0.052	ANOVA (Not Sig), T-test (Not Sig)
	Female	28.09					
TPD * SEX (mm)	**Male**	18.80	F=3.543, P=0.063	1.092	0.584	t=1.872, P=0.064	ANOVA (Not Sig), T-test (Not Sig)
	Female	18.27					
ARCH INDEX* SEX	**Male**	1.71	F=0.314, P=0.577	-0.031	0.055	t=-0.566, P=0.573	ANOVA (Not Sig), T-test (Not Sig)
	Female	1.75					

Table-3: Comparative table of the mean (S.D) value obtained in other studies

		Parameters [Mean (S.D)]							
AUTHORS	**SEX**	**AC1 (mm)**	**PC1 (mm)**	**MM1 (mm)**	**CC1 (mm)**	**PM1 (mm)**	**TPL (mm)**	**TPD (mm)**	**ARCH INDEX (AI1)**
Poosti and Jalali [19]	**Male**	50.76(4.23)	100.95(5.62)	50.6(4.11)	32.19(3.34)	Nil	27.32(3.11)	Nil	Nil
	Female	44.92(4.57)	96.18(6.12)	54.73(3.49)	34.73(3.26)	Nil	36.62(3.02)	Nil	Nil
Nazir *et al.*[17]	**Male**	48.40(3.79)	100.57(5.16)	47.05(3.98)	34.37(3.12)	38.64(3.15)	Nil	Nil	Nil
	Female	47.11(3.52)	94.89(4.87)	50.73(3.62)	32.69(3.23)	35.81(3.13)	Nil	Nil	Nil
Mohammad *et al.* [16]	**Male**	44.37(2.34)	95.47(4.13)	50.6(3.24)	35.35(1.96)	Nil	35.78(1.81)	18.55(2.20)	Nil
	Female	43.70(2.11)	96.18(4.13)	39.54(3.35)	33.91(1.80)	Nil	29.79(2.23)	16.98(2.12)	Nil
Nabil [18]	**Male**	43.70(3.15)	97.15(3.98)	58.59(3.03)	36.06(1.89)	47.29(2.45)	29.73(2.01)	21.17(1.51)	Nil
	Female	48.17(3.08)	99.51(3.70)	48.72(2.82)	30.94(1.78)	48.94(2.32)	25.43(2.04)	20.71(1.39)	Nil
Present study*	**Male**	48.48(4.41)	100.47(6.18)	50.62(4.15)	35.36(3.66)	39.00(3.17)	28.89(3.19)	18.85(3.11)	1.77 (0.23)
	Female	47.2(4.82)	98.47(6.92)	48.77(3.38)	34.73(3.20)	37.53(2.95	27.56(3.43)	17.76(2.60)	1.80 (0.31)

Discriminant Function Analysis

Table-4:Table Tests of Equality of Group Means

Parameter	**Wilks' Lambda**	**F**	**df1**	**df2**	**P-Value**	**Inference**
MM1	0.942	5.858	1	95	**0.017**	**Sig**
PM1	0.944	5.589	1	95	**0.02**	**Sig**
TPL	0.961	3.843	1	95	0.053	Not Sig
TPD	0.964	3.543	1	95	0.063	Not Sig

Table-5: Table Tests of Equality in population covariance matrices and canonical correlation

BOX'S M EQUALITY IN COVARIANCE			EIGENVALUE		
			Function	**Eigenvalue**	**Canonical Correlation**
Box's M		16.878			
F	Approx.	1.611	1	0.155	**0.367**
	df1	10			
	df2	42761.228			
	Sig.	**0.097**			

Tabl- 6: Wilks' Lambda test for predictability into group membership

Test of Function(s)	Wilks' Lambda	Chi-square	df	P-value	Inference
1	0.866	13.429	4	0.009	**Sig**

Table-7:Canonical discriminant function coefficient structured, standardized and unstandardized

Box's M Structure Matrix Coefficients		standardized Canonical Discriminant Function Coefficients	Unstandardized Canonical Discriminant Function Coefficients
Variables	**Function [1]**	**Function**	**Function [b]**
MM1	0.63	0.407	**0.108**
PM1	0.615	0.466	**0.152**
TPL	0.51	0.408	**0.123**
TPD	0.49	0.507	**0.178**

Function [1] - Pooled within-groups correlations between discriminating variables and standardized canonical discriminant functions
Function [b] – Coefficients used for computing group membership value

Table-8:Percentage predictability for group membership

		SEX	Predicted Group Membership		Total
			Male	**Female**	
Original[a]	**Count (%)**	Male	29 (61.7)	18 (38.3)	47 (100)
		Female	15 (30)	35 (70)	50 (100)
Cross-validated[b]	**Count (%)**	Male	28 **(59.6)**	19 (40.4)	**47 (100)**
		Female	16 (32)	34 **(68)**	**50 (100)**

[a]66.0% of original grouped cases correctly classified
[b] 63.9% of cross-validated grouped cases correctly classified

DISCUSSION

Except in extreme cases; of the 32 teeth in humans, at least a few teeth can be recovered in cases of accidents and mass disasters hence; they are routinely used in comparative identification of human remains. Teeth complete development before skeletal maturation, which makes them a valuable sex indicator, even in young individuals. The analysis of dental size and arch dimensions establishes human biological characteristics, such as genetic relationship between populations and the adaptation of humans to their place of residence.

Comparison with other studies

In this study,the mean anterior and posterior circumferences (AC1 and PC1) were measured and the results (AC1: M= 48.48mm, F=47.2mm and PC1: M=100.47mm, F= 98.47mm) were similar to those of Nazi*et al*.[17] onParkistan population with mean values for AC1: M= 48.40mm, F= 47.11mm and PC1: M= 100.57mm, F= 94.89mm respectively. However, when compared with the values reported by [16](AC1: M= 44.37mm, F= 44.92mm and PC1: M= 95.47mm, F= 96.18mm), the Ikwerre exhibited higher values.

The mean inter-canine distance (CC1) for Ikwerrepopulation was found to be M=35.36mm,F=34.723mm which is less than those values recorded by Nabil [18] for both gender of Yemeni population(M=36.06mm, F=35.27mm); but higher than those of Poosti and Jalali[19] and [17] as

they documented values for M=32.19mm, F=30.94mm and M=34.37mm, F=30.94mm respectively. The inter-molar distance(MM1) of the dental arch was wider in males (50.62mm)than females (48.77mm) which was in contrast with other populations[16] documentedthe mean value(M=50.6mm, F=54.73mm) and[17] reported(M= 47.05, F= 54.73) mm. This findings may connote racial and environmental factors which may also have an effect on the results.

The mean total palatal length (TPL) of Ikwerres was measured and found to be M=28.89mm, F=27.56mm which was higher when compared to that of [19] for the Iranian population (M=27.32mm, F=25.43mm). On the other hand, the mean palatal length of Ikwerres was less than that of Malaysian population researched by [16] (M=35.78mm, F=29.79mm). The difference in the results was due to the pattern of jaw growth and development of circumference points that vary between individuals as well as among different circumference points.

The mean total palatal depth (TPD) of Ikwerres was documented and the result (M=18.85mm, F=17.76mm) was similar to the results documented by [16] for the Malaysian Malay population (M=18.55mm, F= 16.98mm). However, when compared with the study by Nabil[18] on Yemeni population (TPD: M=21.17mm, F=20.71mm), the Ikwerres had lower values.

The arch index which is the ratio of the maximum width (MM1) to the maximum length of the cast (TPL) was calculated and observed to be higher in females (1.80±0.31) than in males (1.77±0.23). This indicates a wider arch width to arch length for the Ikwerre population.

Statistical analysis showed that there was a significant difference in the mean values of male and female PM1 and MM1 ($p<0.05$) but no significant difference in other parameters ($p>0.05$). This marked difference is in line with the study by Ross-Powell and Harris[20] who worked on white population with slightly marked difference in the black population; and Abdol*et al.*[21] on 60 Filipinos. But disagrees with the findings of[16] on Malaysian Malays; as no significant difference was observed.

In this study, the measurements for the various dimensions of the dental arch reaffirms the view that male dental arches are greater than that of females ones. In most studies, the arch dimensions depended on the sex of the subjects[18] with lower values in females. The difference in the arch dimensions have been attributed to the fact that the dental arches in males grow larger and for longer than in females during both the preadolescent and adolescent periods[22,23]. However, differences between females and males have been shown not to be systematic across all dimensions in most studies[24,25,26].

Sex categorization using discriminant function analysis (DFA)

The discriminant model for sex categorization was obtained as follows;

Sex = -17.897+ 0.108 (MM1) + 0.152 (PM1) + 0.123 (TPL) + 0.178 (TPD)

Upon execution of the above equation with the new data, sex determination can be done with the adjusted canonical centroids of -0.378 to 0.402; that is, if the product obtained is close to -0.378 the proposed sex is female but if the other centroid obtained is close to 0.402 then the proposed sex is likely male. This model when tested with the present data it derived an 'F' likelihood ratio test with model accuracy of 63.9%. Although prediction using this model is statistically significant ($P<0.01$); however a 63.9% predictability into group membership seems quite low with a better prediction for female (68%) than males (59.6%). This result indicates cautious prediction into group membership using this model.

CONCLUSION

It is evident from the results of this study that dental arch dimensions exhibited continuous range of variation among individuals within the same populations and also race specific differences. The findings of this study reinforces the argument that a single standard arch dimensions cannot be applied for sexual, racial or ethnic grouping.

Although discriminant function analysis successfully predicted 64% of data into groups (sex) and the prediction statistically significant; however a 63.9% predictability into group membership seems quite low; thus suggestive of the fact that the use of odontomery alone may not be effective for sex differentiation.

RECOMMENDATION

The results of the current study are of great value to the anthropologist as well as to the orthodontist in understanding dimensional arch criteria and can also assist clinicians with orthodontic arch wire selection. Furthermore it would also be helpful to prosthodontist in the selection of the correct shape and size of stock impression trays and of suitable molds of artificial teeth for fixed and removable prostheses.

Recommendation

It is strongly recommended that the use of odontometry and palatalrugosocpy as a predictor for sex membership should be investigated to corroborate the findings of this research and such research be carried using a larger sample population.

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