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Original Research Article

Estimating the Sex of Igbo Adults Using Occlusal Tooth Wear

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ABSTRACT

The study estimated sex using occlusal tooth wear. A total of 202 Igbo adults (aged 21 – 60 years), resident in the south-eastern part of Nigeria were used for the study. Those who gave their consent and reached the benchmark for selection were sampled. Tooth wear patterns were obtained using alginate-based impression material obtained from alginate (using a grade IV dental stone). Tooth wear (TW) was scored from the casts using the adjusted Kim's scoring system. Occlusal wear was scored 0-10 according to the pattern and degree of wear. The teeth were numbered: 14, 15, 16, 17, 24, 25, 26, 27, 34, 35, 36, 37, 44, 45, 46 and 47 following FDI nomenclature. Results were analyzed using SPSS (IBM®, version 25.0, Armonk, New York, USA) and Minitab (Minitab® Inc., version 18.0, Pennsylvania). Results values were presented in descriptive statistics, Mann Whitney U test, was used to establish sex and paired t-test for side differences, while Decision Tree using Chi-square Automatic Interaction Detector (CHAID) was carried out to discriminate sex (with age as an influence variable) at 95% confidence limit (with P-values < 0.05 considered statistically significant). Females had higher scores for tooth wear compared to males for all 16 teeth, except 14 and 34.The CHAID model showed that the TW score for LRQ47 was the predictor with the strongest relationship with sex after controlling for age. When the scores were 3; 2; 8; 1; 0– there was 62.5% chance that it was male, while when the score was 5; 4; 7–the possibility it was female was 63.8%. However, there was a better prediction for males (81.1%) when compared to females (40.7%); with an overall accuracy of 62.9%. In conclusion, tooth wear score may not be an accurate stand-alone sex-discriminatory parameter; therefore, it is advisable to use it alongside other available techniques.

Keywords: Occlusal, Tooth, Wear, Sex, Estimation.

1. INTRODUCTION

Humans are products of their genetic makeup and markup; hence, the primary question in every forensic investigation is "what is the sex"? Male and female differ in their structural characteristics (anatomy) as well as functional abilities (physiology). Function is usually a product of structure. Certain bones such as the pelves, because of their morphological adaptation (as a result of their peculiar physiologic roles) have been found to exhibit high sex-discriminatory attributes (with accuracies of up to 95%). Long bones (Limbs) and other irregular bones (clavicle, vertebrae etc.) have also provided highly sex-estimative

accuracies ranging from 75 to 90%. Also, other structures including the skull and certain soft tissues are sex discriminatory. In personal identification, sex estimation plays a key role in reducing the extent of assumptions. [1,2]

Depending on post mortem conditions or how long death has occurred, soft tissues, including bones may grossly deteriorate (or disintegrate in fire incidents), making them useless for certain forensic inquests. Under such situations, attention is directed to those body parts such as the teeth capable of withstanding all sorts of post mortem assaults (environmental, biological, elemental, chemical etc.). The teeth coated with enamel is the strongest known substance in the body [3,4] and as a result will always be available. This characteristic informed its choice for the study.

Victim identification usually begins with sex estimation. Crime rate has increased in recent times, with reports of cultists killing and setting their victims ablaze, ritual killings etc. Identification becomes challenging especially in situations where the body is severely damaged.

Studies have shown that the tooth undergoes morphological changes with age, and specifically, age can be estimated from occlusal tooth wear. [5-11] However, only a few studies have attempted to estimate sex from occlusal tooth wear, while controlling for the age. This study therefore, investigated the reliability of occlusal tooth wear (obtained using the modified Kim's scoring system) in sex estimation among Igbo adults.

2. MATERIALS AND METHODS

It was a cross-sectional descriptive study involving 202 subjects [111 (Males); 91 (Females)] Igbo adult Nigerians between the ages of 21 to 60 years. The study was carried out in the five states that made up the South-eastern Nigeria (Abia, Anambra, Ebonyi, Enugu, Imo). Subjects who met the inclusion criteria and gave their consent were included in the study. Ethical approval was obtained from the University of Port Harcourt Research Ethics Committee, with the reference number UPH/CEREMAD/REC/ 04.

Selection Criteria

Inclusion Criteria

The following criteria were considered:

1. Individuals who are of Igbo extraction by both parents up to the 3rd generation.
2. Individuals with class I dental occlusion, without overcrowding and tooth agenesis.

Exclusion Criteria

1. Individuals with abnormal dental conditions; such as malocclusions and impaction.
2. Those with anomalies of the palate and cleft lips (such as cleft palate and lips).

2.1 Procedure for data collection

Data collection (dental cast models) was carried out following Nandini *et al.* [12]

3.5.1 Subject Selection and Education

Subjects who gave their consent and met the inclusion criteria were selected for the study. Consent was sought through informed consent forms. The procedure as well as the benefits of the study verbally explained to them. The following was explained to the subjects. Subjects biodata, such as State of origin, age, sex, feeding habit (such as carbonated drink consumption rate and vegetarianism) and reference code was collected using Open Data Kit (ODK); a software solution for paper questionnaire used for data collection by field scientists.

3.5.2 Taking tooth impression using alginate

This was done in the following steps:

1) A type II chromatic alginate (Sodium alginate and calcium sulphate) impression material of normal setting (manufactured by Asmy Asade Nig. Ltd) was used to make an imprint of the teeth and the adjacent structures.

2) About 2 scoops of distilled water was measured into a plastic mixing bowl, while 2 scoops of alginate were measured into a cup and added to the water.
3) A wide bladed spatula was used to rapidly mix/swipe the alginate mass against the sides of the bowl to avoid entrapment of air in the mix. This was done at room temperature (23°C) for about 30-45 secs until it turns purple red.

3.5.3 Selecting Impression Tray and Loading Alginate

Perforated stock impression tray was used to load the alginate paste. Perforated spaces on the tray ensured that the solidified alginate was locked and held tight to the tray. This prevents lifting or distortion of the alginate impressions during removal. Two types of tray were utilized for the study; one for the maxillary dental arch and the other for the mandibular. The maxillary tray is closed like a trowel, while for the mandibular; space is created for the tongue. Impression tray do come in different sizes, hence the appropriate size for an individual was selected in making their dental impressions.

3.5.4 Preparing the Mouth for Impression

The mouth was rinsed with water to moisten the teeth and eliminate debris and food particles which may fill up the occlusal surfaces. When the mouth (teeth) is dry, alginate radicals may react with the hydroxyapatite crystals of the enamel forming strong bonds. Alginate tears upon removal if this happens. [13]

3.5.5 Loading the Impression Tray and making Impressions

a. The subject was made to sit on a comfortable chair.
b. The mixture was first rubbed on the occlusal surfaces to fill up the grooves.
c. The mouth was opened and the tray loaded with alginate (to about 3mm thickness from the tray) was placed in position and the mouth closed.
d. The subjects were asked not to apply any pressure, as this would cause the impression to set under strain, leading to distortion or inaccurate cast upon removal. Loading alginate into the tray and taking impression was done within 45 secs after mixing, beyond which setting begins. The chromatic alginate was pink at this stage.

3.5.6 Removal and Inspection of Impression

a. After about 1-2 mins, the impression was considered set (when it turned white) and removed using a firm quick-snap. The index fingers were placed on the buccal sulci breaking the seal between the tissues and the impression tray. The thumb held the handle of the tray, with the other fingers supporting the tray.
b. After removal defects, presence of saliva or blood clot was checked under good lighting condition. And if any, the impression was rinsed in running tap water (and dried immediately with a damp napkin to avoid imbibition), while thick serous saliva and blood cloths were gently removed using a wet camel's hair brush.

3.5.7 Casting and de-casting

a. A type IV grade dental stone ISO 13485-2016 (manufactured by Mr. Dental Supplies Limited, England, United Kingdom) was mixed with water to form a pouty and gently poured into the tray with the impressions facing downwards.
b. The cast was allowed to set and removed (de-casted) thereafter to avoid a perforated ("moth-eaten") appearance.
c. The casts were coded according to the reference code given to the individuals in their ODK forms. This was done to avoid mix-ups.

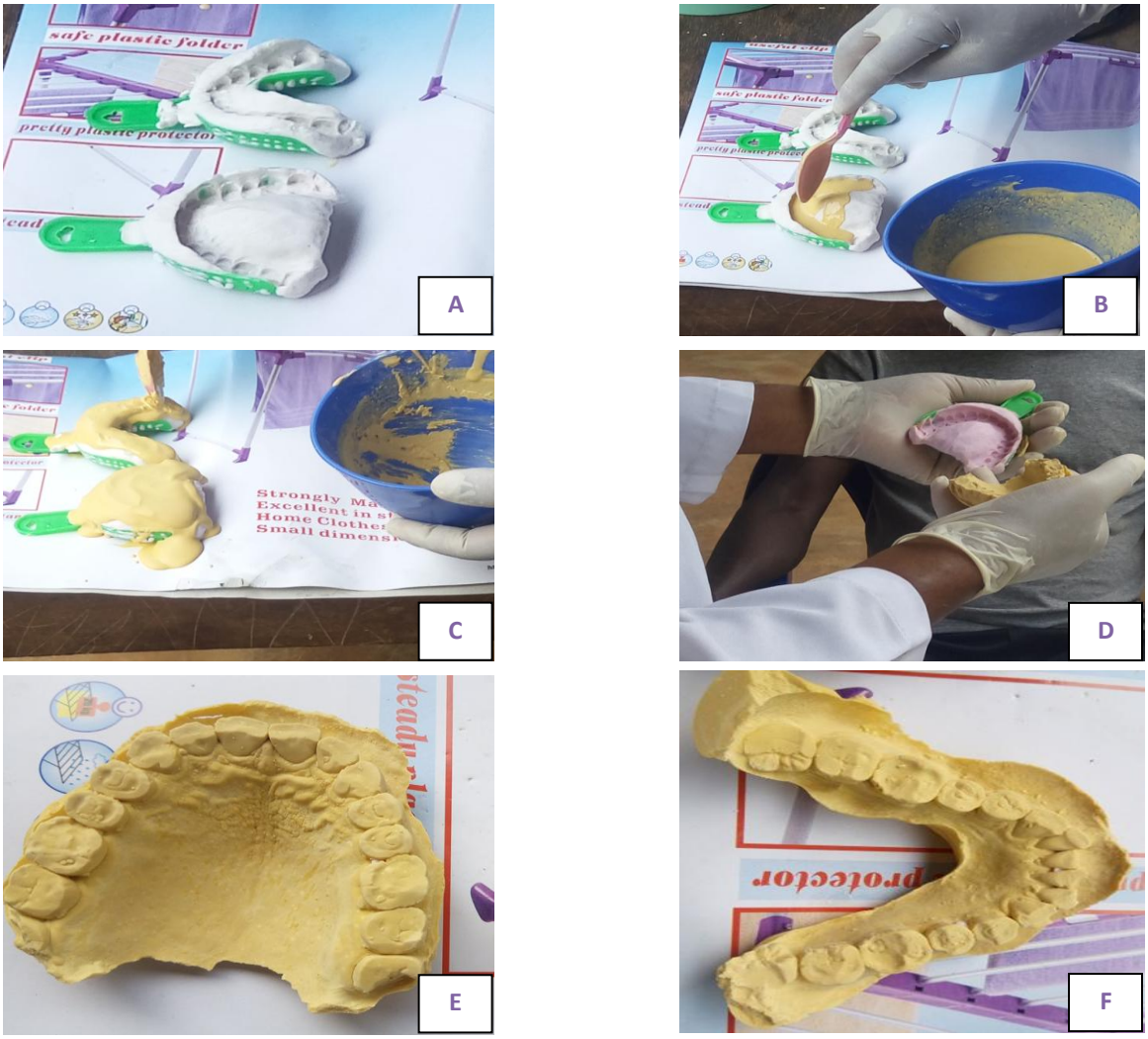

Figure 1: A = Tooth impression, B& C= Filling with Dental Stone, D= De-casting, E & F = Dental Cast

3.5.8 Scoring Tooth Wear Pattern from the Cast

Full maxillary and mandibular impressions were obtained, from the dental cast model prepared using alginate impression material.

All the sixteen (16) permanent posterior teeth were examined for tooth wear with the naked eye under good illumination, using a magnifying glass (manufactured by Ningbo-Hongbo Optical Instrument Co., Ltd. Zhejiang, China ISO 9001, ISO 9000). The teeth were coded following the "*Federation Dentaire Internationale*" (FDI) classification. These includes tooth number (TN) 14, 15, 16, 17, 24, 25, 26,27, 34, 35, 36, 37, 44, 45, 46, 47.

Tooth wear pattern from canine to canine were not considered because of their wide angular variations from individual to individual. The third (3rd) molar (wisdom tooth) which is not usually present in every individual and may sometimes be impacted was also not considered.

The tooth scored was numbered following the world-wide accepted *Federation Dentaire Internationale* (FDI) nomenclature. Pattern, number and the amount of TW (degree of dentin exposure) was observed, measured and assigned scores (0-10) based on the scoring system developed by Kim *et al* [9] and modified by Lu *et al* [11] (Table 1). Three (3) trained research assistant were employed who also observed and independently assigned

scores. Tooth wear was evaluated by two different criteria; pattern and the extent of dentin exposure.

Table 1: Modified Kim's scoring system

SCORE	PREMOLAR	MOLAR
0	No visible wear	No visible wear
1	1P / lL	1P / 1L / 2P / 2L
2	2P / 2L / 1S / lB	3P / 3L / 4P / 4L / 1S / 1B / 2S / 2B
3	2S / 2B	3S / 3B / 4S / 4B
4	Wear on more than 2/3 occlusal surface	-
5	1Pc / lLc	1Pc / lLc / 2Pc / 2Lc
6	2Pc / 2Lc / lSc / lBc	3Pc / 3Lc / 4Pc / 4Lc / lSc / lBc / 2Sc / 2Bc
7	2Sc / 2Bc	3Sc / 3Bc / 4Sc / 4Bc
8	Concavity on more than 2/3 occlusal surface	-
9	Filling, ∗caries, ∗crown (all teeth)	
10	Missing, stump of tooth, pontic, denture (all teeth)	

**If the extent of filling materials or caries does not exceed 1/3 of the occlusal surface so that the degree of occlusal tooth wear can be determined, the appropriate score should be given.*
P, point-like wear facet less than c. 1mm in diameter;
L, linear wear facet less than c. < 1mm in width;
S, surface-like wear facet greater than c. 1mm in diameter;
B, band-like wear facet greater than c. 1mm in width or wear facet involving more than two surface-like wear facets.
'/' means 'or.'
'c'(concavity), the wear of dentin.
Where there are several degrees of tooth wear, the highest value is taken.

3.6 Method of Data Analysis

Data was analyzed using Statistical Package for the Social Sciences (IBM® SPSS version 25.0, SPSS Inc., Chicago, IL, USA). The criterion level for significance was set at 95%; hence $p< 0.05$ was considered significant. Tooth wear scores were expressed as Mean±SD. Sex difference in tooth wear and tooth wear pattern was determined using Mann Whitney U test and paired t-test for side differences, while Decision Tree using Chi-square Automatic Interaction Detector (CHAID) was carried out to estimate sex from tooth wear scores.

3.7 Reliability of the Modified Kim's Scoring System

The reliability of Kim's assessment system as modified by Lu *et al,* [11] was evaluated using Fleiss' Kappa statistics; which determines the inter-rater reliability between the examiners. A 95% significant average concordance (P<0.001) for all tooth wear scores and 95.0% (CI of 86.60-97.02; P<0.001) overall attribute agreement between the evaluators was observed.

3. RESULTS

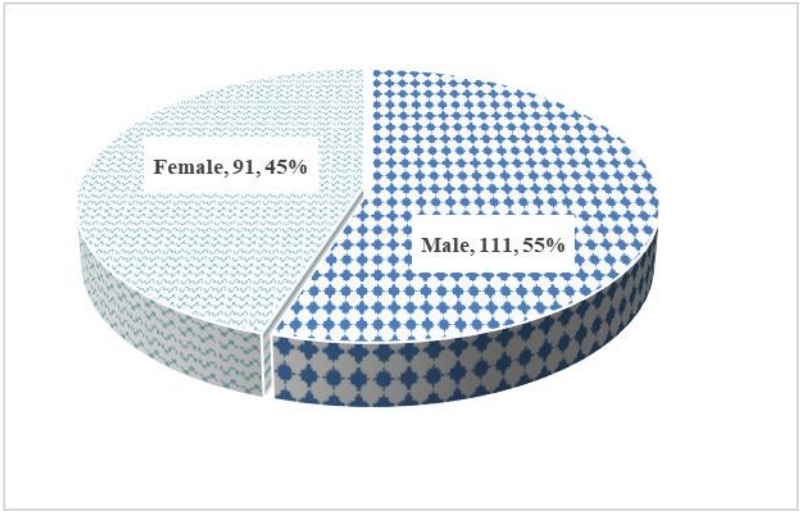

Figure 2: Distribution of the subjects by age and sex

Table 2: Descriptive statistics of occlusal tooth wear score among the subjects

Tooth Number	MALE [N = 111]				FEMALE [N = 91]				ALL [N = 202]			
	Mean	SD	Min	Max	Mean	SD	Min	Max	Mean	SD	Min	Max
14	2.32	1.00	0	5	2.70	1.03	1	5	2.50	1.03	0	5
15	2.98	1.51	1	8	3.07	1.58	1	8	3.02	1.54	1	8
16	3.24	1.35	1	8	3.35	1.42	1	8	3.29	1.38	1	8
17	4.14	1.79	1	8	4.22	1.70	2	8	4.17	1.75	1	8
24	2.57	0.97	1	4	2.80	0.96	1	4	2.67	0.97	1	4
25	2.78	1.11	1	8	2.91	1.30	1	9	2.84	1.19	1	9
26	3.83	1.63	1	8	3.86	1.70	1	9	3.84	1.66	1	9
27	3.84	1.78	1	8	3.75	1.75	1	9	3.80	1.76	1	9
34	2.74	0.86	1	5	3.10	0.84	1	5	2.90	0.87	1	5
35	3.55	1.58	1	8	3.55	1.50	1	9	3.55	1.54	1	9
36	3.60	1.73	1	8	3.63	1.75	1	9	3.61	1.73	1	9
37	3.59	2.18	0	8	3.64	1.70	1	8	3.61	1.98	0	8
44	2.48	0.91	1	5	2.67	0.93	1	4	2.56	0.92	1	5
45	3.27	1.33	1	8	3.01	1.45	1	8	3.15	1.39	1	8
46	3.71	1.88	1	8	3.69	1.86	1	9	3.70	1.87	1	9
47	3.46	2.24	0	8	3.59	1.72	1	8	3.52	2.02	0	8

N = Number of subjects, SD = Standard Deviation

Table 3: Mann Whitney-U test comparing the tooth wear score in male and female subjects

Tooth Number	Sex	N	Mean Rank	Mann-Whitney U	Z	p-value
14	Male	111	92.51	4053.00	-2.52	0.01*
	Female	91	112.46			
15	Male	111	99.88	4871.00	-0.45	0.65
	Female	91	103.47			
16	Male	111	98.90	4762.00	-0.74	0.46
	Female	91	104.67			
17	Male	111	100.22	4908.00	-0.37	0.71
	Female	91	103.07			
24	Male	111	95.64	4400.50	-1.64	0.10
	Female	91	108.64			
25	Male	111	99.59	4839.00	-0.55	0.58
	Female	91	103.82			
26	Male	111	101.26	5023.50	-0.07	0.95
	Female	91	101.80			
27	Male	111	103.47	4831.50	-0.55	0.58
	Female	91	99.09			
34	Male	111	91.16	3902.50	-2.96	0.00*
	Female	91	114.12			
35	Male	111	100.43	4932.00	-0.30	0.76
	Female	91	102.80			
36	Male	111	101.70	5028.00	-0.06	0.95
	Female	91	101.25			
37	Male	111	97.86	4646.50	-1.00	0.32
	Female	91	105.94			
44	Male	111	96.28	4471.50	-1.47	0.14
	Female	91	107.86			
45	Male	111	108.42	4282.00	-1.94	0.05
	Female	91	93.05			
46	Male	111	102.60	4928.00	-0.31	0.76
	Female	91	100.15			
47	Male	111	95.69	4406.00	-1.60	0.11
	Female	91	108.58			

M = Male, F = Female, = Significant at p < 0.05*

Table 4: Paired t-test comparing the occlusal tooth wear score (upper and lower quadrants) of the subjects

Tooth Pair	MALE					FEMALE				
	Paired Differences		Paired t-test			Paired Differences		Paired t-test		
	MD	SE	df	t-value	p-value	MD	SE	df	t-value	p-value
14 vs 44	-0.15	0.12	110	-1.27	0.21	0.03	0.13	90	0.25	0.80
15 vs 45	-0.29	0.17	110	-1.67	0.10	0.05	0.16	90	0.34	0.73
16 vs 46	-0.47	0.21	110	-2.28	0.02*	-0.34	0.20	90	-1.67	0.10
17 vs 47	0.68	0.21	110	3.19	0.00*	0.63	0.19	90	3.36	0.00*
24 vs 34	-0.17	0.11	110	-1.56	0.12	-0.30	0.12	90	-2.38	0.02*
25 vs 35	-0.77	0.16	110	-4.81	0.00*	-0.64	0.19	90	-3.35	0.00*
26 vs 36	0.23	0.10	110	2.28	0.03*	0.23	0.11	90	2.07	0.04*
27 vs 37	0.25	0.20	110	1.24	0.22	0.11	0.15	90	0.72	0.48

** = Significant at p < 0.05, MD = Mean Difference, SE = Standard Error of Mean Difference, df = degree of freedom*

Table 5: Paired t-test comparing the occlusal tooth wear score (right and left quadrants) of the subjects

Tooth Pair	MALE					FEMALE				
	Paired Differences		Paired t-test			Paired Differences		Paired t-test		
	MD	SE	df	t-value	p-value	MD	SE	df	t-value	p-value
14 vs 24	-0.24	0.13	110	-1.91	0.06	-0.10	0.14	90	-0.70	0.49
15 vs 25	0.20	0.18	110	1.12	0.26	0.15	0.23	90	0.68	0.50
16 vs 26	-0.59	0.19	110	-3.13	0.00*	-0.51	0.19	90	-2.64	0.01*
17 vs 27	0.30	0.19	110	1.53	0.13	0.47	0.20	90	2.36	0.02*
44 vs 34	-0.26	0.12	110	-2.26	0.03*	-0.43	0.12	90	-3.54	0.00*
45 vs 35	-0.28	0.14	110	-1.94	0.05	-0.54	0.14	90	-3.80	0.00*
46 vs 36	0.11	0.06	110	1.68	0.10	0.07	0.08	90	0.81	0.42
47 vs 37	-0.13	0.09	110	-1.44	0.15	-0.04	0.03	90	-1.27	0.21

Chi-square Automatic Interaction Detector (CHAID) /Decision Tree (DT) for Sex Estimation

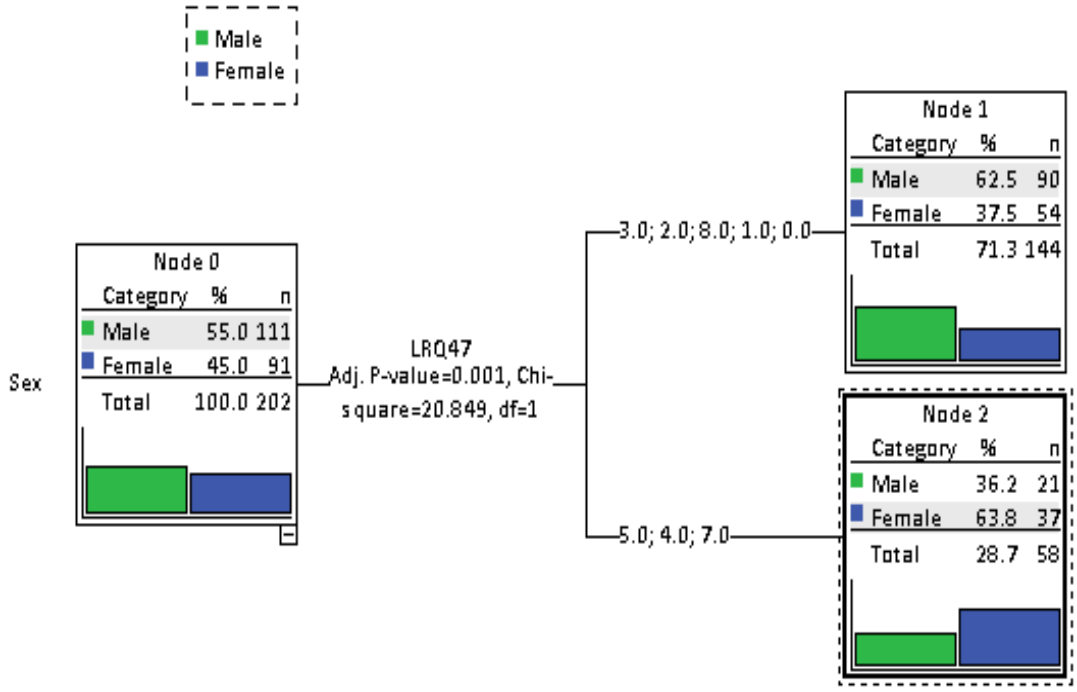

Figure 3: Decision tree for sex categorization using occlusal tooth wear

Table 6: Classification summary for group membership using tooth wear score

Observed	Predicted		
	Male	Female	Percent Correct
Male	90	21	81.1%
Female	54	37	40.7%
Overall Percentage	71.3%	28.7%	62.9%

Results are as presented in Figure 2 & 3 and Table 2 – 6. The distribution of the subjects according to sex was presented in Figure 2, while decision tree for sex categorization was presented in Figure 3. Descriptive statistics of occlusal tooth wear score was presented in Table 2. Mann Whitney U test was presented in Table 3, while paired t-test was presented in Table 4-5. In Table 6, decision tree for sex categorization using occlusal tooth wear was presented.

4. DISCUSSION

The study examined occlusal tooth wear and its ability to estimate sex in Igbo adults. Except TN 27 (M = 3.84±1.78; F = 3.75±1.75), 35 (M = 3.55±1.58; F = 3.55±1.50), 45 (M = 3.27±1.33; F = 3.01±1.45) and 46 (M = 3.71±1.88; F = 3.69±1.86), mean tooth wear score (TWS) were higher in females: TN 14 (M = 2.32±1.00; F = 2.70±1.03), 15 (M = 2.98±1.51; F = 3.07±1.58), 16 (M = 3.24±1.35; F = 3.35±1.42), 17 (M = 4.14±1.79; F = 4.22±1.70), 24 (M =

2.57±0.97; F = 2.80±0.96), 25 (M = 2.78±1.11; F = 2.91±1.30), 26 (M = 3.83±1.63; F = 3.86±1.70), 34 (2.74±0.86; F = 3.10±0.84), 36 (M = 3.60±1.73; F = 3.63±1.75), 37 (M = 3.59±2.18; F = 3.64±1.70), 44 (M = 2.48±0.91; F = 2.67±0.93), 47 (M = 3.46±2.24; F = 3.29±1.72) compared to males (Table 2). Except for TN 14 (U = 4053.00; P = 0.01) and 34 (U = 3902.50; P = 0.00), these differences were not statistically significant.

Differences in TWS for the upper and lower quadrants were evaluated (Table 4) using paired t-test. The lower quadrants were observed to have higher TWS in males, while the reverse is the case in females. These differences were not statistically significant for all tooth pairs in both quadrants, except TN[16 and 46($t_{[df=110]}$ = -2.28; P = 0.02)], [17 and 47($t_{[df=110]}$ = 3.19; P = 0.00)], [25 and 35 ($t_{[df=110]}$ = -4.81; P = 0.00)]and[26 and 36($t_{[df=110]}$ = 2.28; P = 0.03)].

For females, significant difference in TWS was observed in the following pairs[17 and 47 ($t_{[df=90]}$ = 3.36; P = 0.00)],[24 and 34 ($t_{[df=90]}$ = -2.38; P = 0.02)], [25 and 35 ($t_{[df=90]}$ = -3.35; P = 0.00)] and [26 and 36 ($t_{[df=90]}$ = 2.07; P = 0.04)].

Tooth wear score was equally distributed between the right and left quadrants, more of the left teeth have higher TWS compared to the right in both sexes.

Compared to females, only [16 and 26 ($t_{[df=110]}$ = -3.13; P = 0.00)] as well as [44 and 34 ($t_{[df=110]}$ = -2.26; P = 0.03)] had significant difference in tooth wear, while in females, more tooth pairs: [16 and 26 ($t_{[df=90]}$ = -2.64; P = 0.01)], [17 and 27 ($t_{[df=90]}$ = 2.36; P = 0.02)], [44 and 34 ($t_{[df=90]}$ = -3.54; P = 0.00)] and [45 and 35 ($t_{[df=90]}$ = -3.80; P = 0.00)] had significant difference in TWS.

Females were observed to have higher TWS compared to males, as also reported by Berbesque *et al* [14] and Lu *et al*, [11] while Seligman *et al*, [15] Spijker *et al* [16] and Lahari *et al* [8] observed the contrary. Hence both sexes differ in the pattern, degree of tooth wear.

Considering the influence of age in tooth wear, Chi-square Automatic Interaction Detector (CHAID) was used to build a predictive model / decision or classification tree. All 16 teeth were entered into the model. Traditionally CHAID splits predictors (tooth wear scores in our case) into categories (nodes) with approximately equal number of observations, creating all possible cross-tabulations for each category. This process is repeated until the best outcomes are achieved. In our case, only tooth number 47 gave a better prediction (62.9%). Unlike discriminant function analysis, CHAID considers the role of influence variables. Hence, there was need to control for age which has a significant correlation with chronological age.

From the decision tree (Figure 3), following FDI classification, if the following combination of tooth wear scores (3.0; 2.0; 8.0; 1.0 and 0.0) in TN 47, there is 62.5% or 37.5% chances that the unknown individual is a male or female respectively. However, if 5.0; 4.0 and 7.0, it is likely a male (36.2%) or female (63.8%).

Sex estimation using predictive models have been able to achieve 85-90% accuracy, [17-19] while 98.1% has been reported Reddy and Doshi [20] and as high as 99.8% by Litha *et al*. [21] Comparatively, the model predictability is considered poor but a useful adjunct, being statistically significant (P < 0.01).

The CHAID model showed that the TW score for LRQ47 was the predictor with the strongest relationship with sex after controlling for age. There was a better prediction for males (81.1%) when compared to females (40.7%); and overall accuracy of 62.9%; with an accuracy of 62.9%, this value is greater than 50.0%, which exceeds the proportional chance criterion. [22] This shows that, when age is considered, LRQ47 was an above-average estimator of sex; however, the predictive power of a model is more accurate when it tends towards 100%.

Concerning sex estimation, several odontometric parameters; such as dental arch dimensions, [23,24] maxillary dental parameters, [25] buccolingual and mesiodistal dimensions, [21,26,27] crown height and width, [28,29] dental indices [30] as well as cervicoincisal dimensions [31] have successfully been used to estimate sex.

This study in addition to these (other dental sex estimation methods), has found occlusal tooth wear to be sex discriminatory and a potential forensic tool in estimating sex among the Igbo ethnic group. Although scientific and peer reviewed publications on sex estimation using occlusal wear is relatively scarce, despite the documented differences in tooth wear score between both sexes. [14] This study observed significant difference in tooth wear score and females on the average had higher tooth wear score compared to males, suggesting that TWS is sex discriminatory.

5. CONCLUSION

The study evaluated occlusal tooth wear in adult Nigerians of Igbo extraction, and established that sex can be estimated from tooth wear using Kim's scoring system as modified by Lu *et al*. [11]

Occlusal tooth wear accurately estimated sex up to 81.1% accuracy, which is high enough to be considered useful in forensic investigations, considering the availability of the teeth even after intense taphonomic conditions. However, this should be used with caution as other factors some of which maybe geographic, functional (biting and chewing force etc.) or parafunctional (bruxism) could also affect tooth wear.

Conflict Of Interest: There was no conflict of interest among the authors.

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