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Morphometry of the Occipital Condyle and Basilar Process of Nigerian Skulls.

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ABSTRACT

Background: Effective surgical approaches and conclusive forensic investigations will require a well-documented comparative data for specific regions. This study was carried out to generate Nigerian specific morphometric data for the occipital condyle and basilar process and evaluate its application in forensic and clinical anatomy using macerated skull bones. **Methods:** A total of 141 adult Nigerian skull bones comprising of 126 males and 15 females were used for this study. Side specific (left [L] and right [R]) morphometric measurements were taken for the occipital condyle [OC] (length, maximum and minimum width [MxOC & MnOC width], post and anterior intercondyle distance [AICD and PICD]). OC morphology was determined by shape and analysis was carried out using the Statistical package for Social Sciences (SPSS IBM® version 23) t-test was used in assessing sex differences in the measured parameters with confidence level set at 95% and $P<0.05$ was considered significant. **Results:** The result obtained showed an equal distribution of oval and oblong shaped OC (27% for both), with less frequent crescentic shaped OC (19.9%). The mean (±S.D) of studied parameters were; L-OC Length = 20.98±1.88mm, R-OC length = 20.52±1.93mm, L-MxOC width = 15.11±1.53mm, R-MxOC width = 14.26±1.59mm, L-MnOC width = 10.85±1.23mm, R-MnOC width = 10.76±1.30mm, AICD = 18.09±2.15mm, PICD = 30.85±2.98mm and BP length = 29.37±3.85mm. The paired sample t-test showed that only the MnOC width was bilateral, while OClength and MxOC width were significantly asymmetrical ($P<0.001$).The t-test showed that all variables except for OC length and MnOC width were significantly larger in males ($P<0.05$). When the dimensions of the Nigerian skull were compared with foreign values, high racial variability was observed and we had average OC length; not very short neither long, which was relatively safe for OC resection during surgical intervention at that region. **Conclusion:** It could be concluded that sex, side and racial differences are observable features of the occipital condyle and its morphometric relationship to other structures are useful to forensic experts and surgeons.

Keywords: *Morphometry, Occipital condyle, Basilar process, Nigerians.*

INTRODUCTION

Morphometric studies are directed towards quantitative description by measuring the human structures with key emphasis on relating them with other structures (Gökceet al., 2014).[1] Morphological and morphometric data are generally considered as good comparative materials for evaluating deviations from the normal age-related changes and assigning sex to human remains (Cardoso and Saunders, 2008),[2] and they could also serve as guide during surgical intervention. Craniometry is an essential aspect of anthropometry which involves the measurement of cranial features so as enable proper and effective classification of people based on ancestral linage, race, sex, intelligence, criminal temperament, and abnormalities (Gould, 1993; Carroll, 1994).[3,4]

The cranial base anatomy is of great significance to anthropology as its structural orientation has been applied in various subfields of anatomy (Graw, 2001; Wescottet al., 2002; Stojanowksiet al., 2002;

Cicekcibasiet al., 2004).[5-8] The occipital condyle (OC) and basilar process (BP) are structures located at the skull base which forms part of the floor of the cranial cavity which by location, differentiates the brain from facial structures and suprahyoid neck (Rautet al., 2012).[9]

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Various part of the cranial base has been applied in clinical, forensic as well as embryologic evaluation (Dowd et al., 1999; Spektoret al., 2000; Villavicencio et al., 2001; Cicekcibasiet al., 2004).[8,10-12] The OC and BP have been reported to exhibit high racial and ethnic variations (Cicekcibasiet al., 2004; Le et al., 2011; Yu et al., 2015),[8,13,14] with higher values reported for the Asians (Bozbugaet al., 1999; Yu et al., 2015; Salujaet al., 2016),[14-16] and lower values for the Caucasians and Australians (Wen et al. 1997; Bazyatet al., 2014),[17,18] while for Africans the values fall between values of Asians and Caucasians (Salihet al., 2014; Agnihotriet al., 2014).[19,20]

Only a few studies have reported morphometric values for the basilar process (clivus), with dimensions ranging from 24mm to 27mm (Oliviera, 1975; Wescott and Moore-Jansen, 2001),[21,22] and higher values for whites when compared to blacks (Wescott and Moore-Jansen, 2001).[22] Le et al., 2011;[13] Bozbugaet al., 1999;[14,15] Yu et al., 2015 Lang and Hornung, 1993;[23] have suggested that the inconsistencies in the morphometric values of the OC in different population could be attributed to differences in data acquisition, methodology and genetic endowment. Good knowledge of the morphometry of the occipital condyles are very important in surgical interventions, for example, the need to carryout OC recession during various surgical approaches to pathological conditions at the posterior part of the cranial base (Agnihotriet al., 2014; Kalthuret al., 2014; Parvindokhtet al., 2015).[20,24,25]

Morphometric studies of the OC is well documented with scanty research on the BP. There is dearth research on the OC and BP of Nigerian population. Therefore this study was carried out to provide reliable morphometric data of the OC and BP of Nigerian well macerated skull bones, and to determine the importance and relevance in clinical studies.

MATERIALS AND METHODS

A total of 141 (126 males and 15 females) adult skull bones of Nigerian descent were used for the study. The study was designed as a cross-sectional analytical research involving direct linear measurement of morphologic attributes of the skull base parameters. The well-macerated, and preserved human skull bones were obtained from the Anatomy Museum of selected Nigerian Universities. The bones obtained in this study were of undetermined age but were observed to have attained post-ossification state without any form of bone deformity and processing damages.

Six (6) measurements (length of Occipital condyle [LOC], minimum Occipital condyle width [MnOCW], maximum Occipital condyle width [MxOCW], anterior intercondylar distance [AICD], posterior intercondylar distance [PICD], length of the basilar process [LBP]) were obtained from the skull base. In obtaining the morphometric data, the skulls were placed on a drawing board with the occipital region facing superiorly, reflecting the foramen magnum. The skulls were held firmly on the board using L-shaped constructed pin-clamp while direct linear measurements were obtained using a pair of spring divider and digital veniercaliper, with an accuracy of 0.01mm. All measurements (in mm) were taken thrice and the average values documented.

Landmarks and guides for morphometric measurements

There skull dimensions investigated and the guidelines for taking these measurements are provided as follows;

[1] LOC: The length of the right and left occipital condyles (LOCright and LOCLleft) is measured as the distance from the anterior tip to the posterior tip of the occipital condyles ([Figure 1]; Line BC).

[2] MnOCW: The minimum width of the right and left occipital condyles (MnOCWright and MnOCWleft) were measured as the distance of the midpoint of anterior left margin and right margin of occipital condyle ([Figure 1]; xa - xb).

[3] MxOCW: The maximum width of the right and left occipital condyles (MxOCWright and MxOCWleft) is measured as the distance of the midpoint of the posterior left margin and right margin of occipital condyle ([Figure 1]; ya - yb).

[4] AICD: Measured from the anterior tips of the right and left occipital condyles ([Figure 1]; Line BC).

[5] PICD: Measured from the posterior tips of the right

and left occipital condyles ([Figure 1]; Line F).

[6] LBP: The maximum length of the basilar process measured from basion to hormion ([Figure 1]; distance from A to line BC).

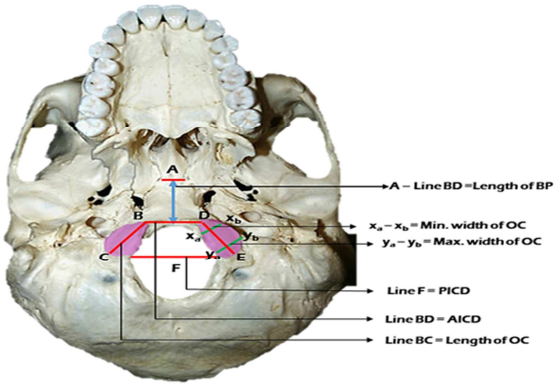

Figure 1: Landmarks and measurements of the OC and BP dimensions

Data Analysis

The data from this study were analysed using the Statistical Package for social Sciences (SPSS IBM® version 23). Student t-test was used in assessing sex difference in the measured parameters, while side difference was determined using paired t-test. Confidence level was set at 95% and P<0.05 was regarded as significant.

RESULTS

[Table 1] shows the mean values of the ant ICD, post ICD and BP Length of males and females. The mean anterior intercondylar distance for male was 18.22±2.23mm and 17.02±0.67mm for female while the posterior was 31.07±3.07mm for males and 29.04±0.84mm for females. The mean length of the basilar process (BP) was 29.73±3.88mm and 26.38±1.71mm for males and females respectively. The t-test for unilateral measurements showed that the mean values of males were significantly greater than mean values of females for the Ant. ICD [t=3.858, P=0.001], Post. ICD [t=4.531, P<0.001], and BP Length [t=3.969, P<0.001]. [Table 2] shows the mean values of the left (R) and right (R) OC Length, MnOCW, and MnOCW of males and females. The L and R occipital condyle (OC) length was 21.03±1.95mm and 20.52±2.01mm for males and 20.52±1.12mm and 20.44±1.13mm for females. The L & R maximum occipital condyle (MxOC) while the L & R minimum occipital condyle (MnOC) was 10.85±1.26mm and 10.74±1.33mm for males and 10.92±0.96mm and 10.91±0.98mm for females respectively. The t-test showed that males had significantly higher values than the females for L-MxOCwidth [t=4.219, P<0.001], R-MxOC Width [t=3.025, P=0.004], while the R & L OC length, and R-&L-MnOC width of males and females were not significantly different (P>0.05).

[Table 3] shows the comparison of paired parameters of the occipital condyle and the extent of difference observed for the parameters for males and females. Bilateral asymmetry was observed for OC Length [t=4.302, P<0.001], MxOCwidth [t=6.965, P<0.001] in males and also in females for OC Length [t=2.314, P=0.036], and MxOC Width [t=21.804, P<0.001]; while the MnOC width was symmetrical in both males [t=0.958, P=0.340] and females [t=0.139, P=0.340].

Table 1: Mean values of measured unilateral parameters and sex comparison.

Variables	Male (N=126)	Female (N=15)	P-value
Ant. ICD (mm)	18.22±2.23	17.02±0.67	0.001
Post. ICD(mm)	31.07±3.07	29.04±0.84	<0.001
BP Length (mm)	29.73±3.88	26.38±1.71	<0.001

Note: Ant. ICD=Anterior Intercondyle distance, Post. ICD=Post Intercondyle distance, BP=Basilar process
N=distribution, P-value=probability value.

Table 2: Mean values of measured bilateral parameters and sex comparison.

Variables	Right		P-value	Left		P-value
	Male (N=126)	Female (N=15)		Male (N=126)	Female (N=15)	
OC Length (mm)	20.52±2.01	20.44±1.13	0.279	21.03±1.95	20.52±1.12	0.147
MnOCW (mm)	10.74±1.33	10.91±0.98	0.451	10.85±1.26	10.92±0.96	0.463
MxOCW (mm)	14.39±1.62	13.20±0.68	0.004	15.22±1.57	14.17±0.61	<0.001

Note: R=Right, L=Left, MxOC= Maximum Occipital condyle, MnOC= Minimum Occipital condyle.
N=Distribution, P-value=Probability value.

Table 3: Evaluation of laterality in male and female skulls using paired sample t-test.

Sex	Parameter	Comp.	Paired Differences			t-value	P-value	Inf.
			M.D	S.D	SE M.D			
Male (N=126)	OC Length (mm)	R vs L	0.51	1.32	0.12	4.302	<0.001	S
	MxOC Width (mm)	R vs L	0.84	1.35	0.12	6.965	<0.001	S

	MnOC Width (mm)	R vs L	0.11	1.25	0.11	0.958	0.34	NS
Female (N=15)	OC Length (mm)	R vs L	0.08	0.13	0.03	2.314	0.036	S
	MxOC Width (mm)	R vs L	0.98	0.17	0.04	21.804	<0.001	S
	MnOC Width (mm)	R vs L	0.01	0.26	0.07	0.139	0.891	NS

Note: R=Right, L=Left, MxOC= Maximum Occipital condyle, MnOC= Minimum Occipital condyle.
N=Distribution, Comp.=Comparison, M.D=Mean difference, S.D=Standard deviation, S.EM.D=Standard error of the mean difference,, R=Right, L=Left, t-value=t-test value, P-value=Probability value, Inf.=Inference (S=Significant, NS=Not significant)

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DISCUSSION

This study investigated the normal morphometry of the occipital condyle and basilar process of the occipital bone and observed that the mean length of the occipital condyle (LOC) for this population were 20.98±1.88mm for the right and 20.52±1.93mm for the left. The mean occipital condyle (OC) length for this study was similar to values [20.66mm] of Sudanese but smaller than the values reported by Lang and Hornung (1993) [22.9mm], for the Germans, Westcott and Moore-Jansen (2001),[6] [23.2±2.9mm and 22.0±2.3mm for Black male and female respectively and 24.7±2.7mm and 22.8±2.2mm for White male and female respectively], Cicekcibasiet al. (2004),[8] [24.36mm], 22.61±2.3mm for the right and 22.36±2.3mm for the left by Mahajan et al. (2011),[26] for Indians, Yu et al. (2015),[14] for Chinese [22.75±2.90mm], Other researchers have also reported varying mean length of the OC of 13.59mm(Oliver, 1975),[27], 22.9mm; right range of 15-27mm and left range of 15-29mm for Germans (Lang and Hornung, 1993),[23] 21 mm; range 18-24mm for Americans (Wen et al., 1997).[17] Kavithaet al. (2013),[28] reported 21.97mm and 22.34mm for the right and left respectively while Salujaet al. (2016),[16] reported mean values of 22.75±2.90mm for Indians.

Due to the irregularity in the dimension of the width of OC, this study evaluated two dimensions; minimum (MnOC) and maximum (MxOC) width. The mean MxOCwidth for the studied Nigerian skull was 15.11±1.53mm for the left and 14.26±1.59mm for the right, while the MnOC was 10.85±1.23mm for the left and 10.76±1.30mm for the right. The mean min and max OC width obtained in this study were greatly different (both at the upper and lower limit) form the values reported by other researches; as Bozbugaet al. (1999),[15] reported 11.3mm for right and 11.4mm for the left condyles of Turks, which was similar to the result by Mahajan et al. (2011),[26] who also reported who reported 11.07±2.41mm on right and 11.42±2.31mm on left condyles of Indians, however, different from the 12.2±1.2mm (R) and 12.4 ±1.5mm (L) reported by Avicet al. (2011).[29]

The mean anterior (AICD) and posterior intercondylar (PICD) distances for the Nigerian skulls were found to 18.09±2.15mm and 30.85±2.98mm. The mean AICD observed in this study was larger than the values;15.39±7.0mm, 17.63mm and 17.81±2.93mm reported by Agnihotriet al. (2014),[20] Kumarand Nagar (2014),[30] and Salujaet al. (2016),[16] respectively, but lower than the values of Naderiet al. (2005),[31] and Mahajan et al. (2011),[26] as they reported 21mm, 21.28±3.03mm, 21.28±3.03mm. However the mean PICD obtained in this study was much smaller than the values of Naderiet al. (2005),[31] [41.6mm], Mahajan et al. (2011),[26] [40.61±3.34mm], Agnihotriet al. (2014),[20] [35.60±8.4mm], Kumarand Nagar (2014),[30] [42.02mm] and Salujaet al. (2016),[16] [38.91±4.16mm].

The AICD and PICD are significant in defining the relative orientation of the occipital condyles. This dimensional difference between the AICD and PICD defines the anterior and posterior angle of the occipital condyle; which indicates the orientation of the space occupied by the condyle with the foramen magnum centrally placed; thus a closer distance and smaller angle of the antero-posterior orientation and narrow intercondylar space would require more bone removal when surgically accessing the posterior cranial base from the condyles (Dowd et.al., 1999).[10] In this study, the males and females AICD were significant different; which is a point for the need to slightly vary technique during surgical intervention. Cicekcibasiet al. (2004),[8] explained that the intercorrelation between the significantly wider foramen magnum in males (Catalina-Herrera, 1987),[32] may have impacted in the observed significantly wider AICD. The dimensional relationship could also be attributed to structural relationship between the OC and foramen magnum.

Bilaterality in symmetrical organisms have been a way of understanding developmental favouritism. This event has made comparison of bilateral structure an integral aspect of investigating human morphometric

differences. This study observed that for both males and females, the left and right OC length and MxOC width were significantly different; with the left being greater than the right, However the MnOC width was bilateral. Asymmetry in OC dimensions has been reported by Agnihotriet al. (2014),[20] and Bazyatet al. (2014),[18] in which they stated that the right OC parameters had mean values significantly greater than the left; however, Lang (1995),[33] Cicekcibasiet al. (2004),[8] and Tale et al.'s (2016),[34] reported no significant bilateral differences in the condyle parameters.

The hypothesis of difference in data acquisition (radiologic, osteometric and photogrammetric) report by Lang and Hornung (1993),[23] inconsistencies in collection methods (Bozbugaet al., 1999),[15] and genetic endowment (Le et al., 2011; Yu et al., 2015);[13,14] as well as racial/ethnic differences (Lang and Hornung, 1993; Lang, 1995; Bozbugaet al., 1999; Cicekcibasiet al., 2004),[8,15,23] are undoubtedly factors which could impact on the range differences in the value obtained in morphometric studies.

CONCLUSION

The difference in the measured dimensions of the skull of Nigerian origin when compared with other parameter was an indication of racial differences and similarities. It cannot be said that the occipital condyle exhibits bilaterality as the left and right side were significantly different. Therefore sex and side differences must be considered during surgical approach. Sex differences in the measured dimensions is an indication of its usability in forensic and also serve as a comparative guide for careful surgical approach and occipitoatlantoaxial stabilization instrument designs.

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