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Research Article

Retrospective CT Study on Orbital Dimensions and Their Role in Sex Determination

Beryl S Ominde*, Wilson Iju and Patrick S Igbigbi

Department of Human Anatomy and Cell Biology, Delta State University, Abraka, Nigeria

***Corresponding Author:** Beryl S Ominde, Department of Human Anatomy and Cell Biology, Delta State University, Abraka, Nigeria.

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Abstract

Background: The knowledge of the variant morphometry of the orbits is useful in the diagnosis of orbital pathology, planning of orbital surgery and in forensic identification of unknown skull bones. This study aimed at determining the dimensions of the orbits and their accuracy in sex prediction.

Materials and Methods: The orbital width, height, interorbital and biorbital distances were measured on computed tomography images of 336 adult Nigerians after obtaining ethical approval. Using Statistical Package for Social Sciences, Version 23, the gender and side differences were assessed using Students' t-test. Significance was considered at $p < 0.05$. Discriminant function analysis was used to evaluate the accuracy of using the measurements for sex determination.

Results: The orbital measurements showed significant side and gender differences ($p < 0.05$). The left orbital width was the most sex discriminating variable (77.1%) while the overall accuracy of sex prediction using all variables was 79.2%.

Conclusion: The dimensions of the orbits showed significant sexual dimorphism and moderately high accuracy in sex prediction. Therefore, the orbits could possibly be used as an auxiliary method for sex determination in our studied population.

Keywords: Orbit; Height; Width; Sex; Prediction; Forensic; Identification

Introduction

The orbits are quadrilateral pyramidal-shaped cavities located on either sides of midsagittal plane of the skull between the cranium and facial bones [1,2]. Its quadrilateral base forms the orbital aperture which is anteriorly located and usually superficial [3]. The contents of the orbits include the eyeballs, extraocular muscles, lacrimal apparatus, neurovascular structures and connective tissue fat pad [4,5]. The normal dimensions of the orbit are important in ophthalmology, maxillofacial surgery and neurosurgery [6,7]. They aid in the diagnosis, surgical planning and postoperative follow-up for craniofacial syndromes, and orbital diseases such as extraocular muscle tumours, infections, trauma and, Grave's disease [8,9]. Surgical procedures involving the orbits include; orbital decompression, optic nerve decompression, vascular ligation, enucleation, evisceration, and exenteration [4]. The awareness of orbital dimensions is allied with a favorable surgical outcome through the restoration of normal anatomy and fewer iatrogenic complications [4,10].

Forensic dentistry involves the personal identification of unknown individuals from skeletal remains in mass disasters such as plane crashes, earthquakes and fire accidents [11,12]. The orbital aperture has been utilized in personal identification owing to its population, racial and geographical variations besides its superficial location and easy accessibility [3,7]. The racial variation in orbital dimensions is due to evolutionary processes and inheritable mutations acted upon by natural selection with subsequent selective adaptation of humans to their environment [2,13]. The orbital cavities are small and squared in males while in females, these cavities are larger and round [13]. The gender differences appear after puberty due to the male skulls manifesting secondary sexual characteristics while the female skull remains infantile [4]. The orbital dimensions show significant gender differences in some populations [5,11]. Discriminant function analysis [DFA] of the orbital variables has shown that they can accurately be used as auxiliary tools for sex determination in some populations [3,11,13].

The orbital index (OI) is the proportion of orbital height to width multiplied by hundred [9]. It is used to quantitatively determine the shape, size and symmetry of the orbits in different population groups [4,13]. The variations in OI are caused by the different craniofacial developmental patterns that depend on race, ethnicity, geographical, social and dietary background [2]. The OI plays a vital role in the interpretation of fossil records, classification of skulls in forensic medicine as well as exploring evolutionary trends and ethnic differences [1,7]. It is standardized and can rapidly be measured in the living and the deceased, hence allowing numerical quantification of descriptive features [14]. Microseme orbits (OI ≤ 83) have larger width than height and are commonly in blacks. They are small, broad, and have a rectangular aperture. The mesoseme orbits (OI= 83-89) are intermediate in size and are mainly in the white races and Caucasians [7,15]. Megaseme orbits (OI > 89) have a larger height than the width. Additionally, they are large, narrow and are predominant in yellow races (Orientals) except the Eskimos where the orbital opening is round [7,9].

Quantitative methods of sex determination are more reliable as expert witnesses in the courtroom than subjective visual descriptions due to low inter-observer variation [3]. The dimensions of the orbits have been measured using calipers or rulers on dry skull bones or on volunteers [3,13,15,16]. These may be inconvenienced by the irregular outline of the skull that makes it non-reproducible [5]. Therefore, radiologic measurements are more accurate, reproducible and reliable in forensic anthropology especially in the absence of deoxyribonucleic acid (DNA) samples and fingerprints, as in cases of extremely decomposed or charred remains. Computed tomography (CT), unlike radiography, isn't limited by the inherent magnification and superimposition of structures hence, it provides accurate bone measurements that can be utilized in forensic medicine [17]. It is also preferred in the clinical evaluation of the complex anatomy of the orbits for diagnosis, follow-up and surgical planning of orbital pathology [5].

There is paucity of data regarding the CT measurements of the orbital aperture in Delta State Nigeria. Peculiar features of a population demand regional studies of the orbits that will support better surgical management of orbital pathologies. This study therefore aimed at assessing the orbital dimensions and evaluate their accuracy in sex prediction.

Materials and Methods

This study adopted a retrospective cross-sectional approach. The CT data stored at the Radiology department of a Teaching Hospital in Delta State, Nigeria were used after obtaining approval from the Hospital's Research and Ethics Committee (EREC/PAN/2020/030/0371). Brain CT images were selected using the purposive sampling technique. Images of patients aged 20 years and above who were referred to the radiology department between 1st June 2015 to 30th June 2020 with chronic headache, suspicious stroke or pulmonary embolism and history of trauma were utilized. These images were acquired using a 64 slice CT scanner (Toshiba Aquilon, Japan,2009) at 120kV and 300mA and thereafter stored in the Picture Archiving Communications Systems (PACS). The images of patients aged less than 20 years and those with evidence of any craniofacial abnormality such as congenital lesions, tumours, facial fractures or previous orbital surgery were excluded from this study.

The age and gender of the patients were recorded on a datasheet. Using bone window, the margins of the orbital aperture were identified on coronal sections and the orbital dimensions were measured bilaterally using a digital caliper calibrated in cm. The orbital width (OW) was measured as the maximum distance between the medial and lateral walls while the orbital height was measured as the maximum vertical diameter between the orbital roof and floor (Figure 1A) [8]. The interorbital distance (IOD) was defined as the minimal distance between the medial orbital walls in coronal planes (Figure 1B) [8]. The longest distance between the lateral margins of the right and left orbital apertures was the biorbital distance (BOD) (Figure 1B) [5].

The study used Statistical Package for Social Sciences (SPSS) for Windows, Version 23.0 (Armonk, New York: IBM Corp) to analyze the data. The data were summarized in means and standard deviations based on gender and 10 years' age groups. The gender differences in the orbital dimensions were evaluated using the in-

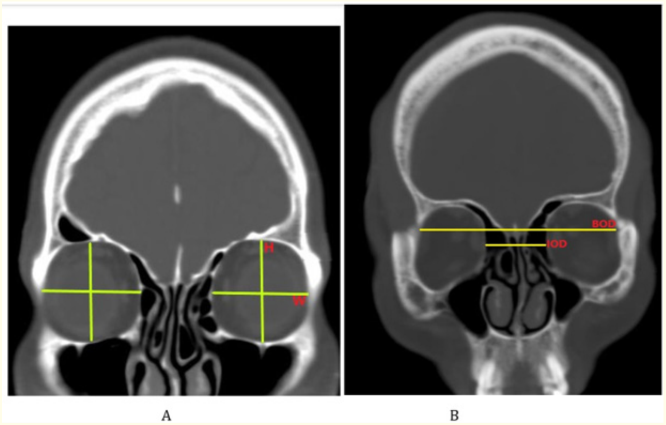

Figure 1: Reformatted coronal slices depicting the measurement of; A: Orbital height (H) and width (W) B: Biorbital Distance (BOD) and Interorbital Distance (IOD).

dependent t-test while the differences between the right and left parameters were assessed using the paired t-test. The analysis of variance (ANOVA) was used to determine the metric differences in the various age groups. Pearson's correlation test was used to determine the correlation between age and the orbital variables as well as the correlation between the various metric parameters. The orbital index (OI) was calculated as (orbital height/orbital width) *100 [17]. Using the OI, the orbits were classified as either megaseme (OI ≥ 89), Mesoseme (OI = 83-89) and microseme (OI ≤ 83) [6]. The Chi-square test was used to determine the association of the orbital categories with the side of orbit and gender. Statistical significance was considered at $p < 0.05$.

Discriminant Function Analysis (DFA) was performed with sex as the grouping variable. Each metric parameter was subjected to univariate analysis while multivariate analysis was conducted using all the measured parameters. Discriminate function equation was derived from the calculated coefficients and constants. Cross-validation of the outcome was done using the "leave one out classification" analysis. The Discriminant functional scores of males and females were determined by incorporating the mean of the measurements of each gender in the equation; Discriminant functional score (D) = (P0) +(P1X1) + (P2X2) + (P3X3) + (P4X4). The function P0 was a constant, P1-P4 were the calculated coefficients and finally, X1-X4 were the measured orbital parameters. The average of the group centroids was used as the sectioning point for sex discrimination whereby, values above the sectioning point classified the cases as males while those below the sectioning point were regarded as females [18].

Results

This study evaluated 672 orbits on skull images of 336 patients: 199 males (59.2%) and 137 females (40.8%). The age of the patients ranged from 20 years to 99 years with majority of the patients being in the 50-59 years (67, 19.9%) followed by 60-69 years (55, 16.4%), 40-49 years (52, 15.5%) and 30-39 years (50, 14.9%) age-groups. Lower frequencies were observed in the 70-79 years (13.7%) and 20-29 years (40, 11.9%) age-groups. The advanced age-groups had the least number of patients namely; 80-89 years (19, 5.7%) and 90-99 years (7, 2.1%). The average age of all the patients was 53.29 ± 18.18 years.

The mean orbital width and height was 3.577 ± 0.318 cm and 3.769 ± 0.299 cm correspondingly. These measurements were larger in males than in females bilaterally. The right orbit had larger dimensions than the left orbit in both males and females. The gender and side differences in these variables were statistically significant ($P < 0.05$) (Table 1). Table 2 shows the orbital height and width in various population groups according to gender. The mean OI was 105.4 ± 7.825 and showed significant gender differences bilaterally. Furthermore, the OI of the right orbit in males was significantly larger than that of the left ($p = 0.032$). The mean OI in various study populations is summarized in Table 2. The average BOD and IOD in the present study was 10.052 ± 0.972 cm and 2.960 ± 0.302 cm respectively besides being significantly larger in males than in females ($P < 0.05$) (Table 1). These parameters have been compared with the mean IOD and BOD in other studies (Table 3). The ratio of IOD to BOD was 0.3 in the study sample and in both sex groups. All the metric variables herein did not show any significant differences in the various age-groups ($P > 0.05$). The peak OI was at the 40-49 years' age-group followed by 50-59 years' age-group (Table 4).

Classification of the orbits based on the average OI in males (106.6 ± 7.665) and females (105.4 ± 8.004) revealed the megaseme type in both genders. This type was the most predominant (436, 64.9%), while microseme orbits were the least prevalent (97, 14.4%) in the studied sample. Based on this classification, orbital

	Side	Gender		
		Males	Females	P value¶
Orbital width (cm)	Right	3.685 ± 0.258	3.433 ± 0.397	0.001*
	Left	3.673 ± 0.258	3.427 ± 0.274	0.001*
	Average	3.679 ± 0.258	3.430 ± 0.340	0.001*
	$^{\beta}$P value	0.038*	0.022*	
Orbital Height (cm)	Right	3.960 ± 0.320	3.620± 0.282	0.001*
	Left	3.887 ± 0.282	3.609 ± 0.278	0.001*
	Average	3.923 ± 0.303	3.615 ± 0.280	0.001*
	$^{\beta}$P value	0.016*	0.043*	
Orbital index	Right	107.7 ± 8.240	105.3 ± 8.109	0.001*
	Left	105.5 ± 7.093	105.3± 7.901	0.001*
	Average	106.6 ± 7.665	105.4 ± 8.004	0.001*
	$^{\beta}$P value	0.032*	0.129	
BOD (cm)		10.32 ± 0.839	9.66 ± 0.102	0.001*
IOD (cm)		3.032 ± 0.314	2.855 ± 0.249	0.001*

Table 1: Gender and side differences in the orbital metric variables.

¶ Independent t-test for gender differences $^{\beta}$ Paired t-test for side differences

*P value considered significant at < 0.05 IOD- interorbital distance, BOD-biorbital distance.

Author	Country	Method	N		Height (mm)	Width (mm)	Orbital index	Orbital class
Bankole., *et al.* [19]	Nigeria	Plain radiographs	150	M	44.06 ± 4.30	42.87 ± 4.60	103.33 ± 12.50	Megaseme
				F	44.26 ± 3.88	42.37 ± 4.95	105.25 ± 10.77	Megaseme
		(Ikweres and Kalabaris)	150	M	42.67 ± 3.48	41.14 ± 3.09	103.98 ± 8.22	Megaseme
				F	42.22 ± 3.82	41.14 ± 3.29	102.92 ± 9.49	Megaseme
Ebeye and Otikpo [16]	Nigeria	Volunteers (Urhobos)	388	M	33.01 ± 3.22	42.24 ± 2.64	78.15 ± 0.82	Microseme
				F	31.92 ± 3.07	40.82 ± 3.29	78.5 ± 0.6	Microseme
Pereira et al. [12]	Brazil	CT	107	M	34.92 ± 2.12	44.15 ± 2.17		
				F	34.35 ± 2.09	42.00 ± 2.03		
Khademi and Bayat, [10]	Iran	CT	120		32.14 ± 1.57	38.49 ± 2.35	88.65 ± 8.90	Mesoseme
Botwe., *et al.* [1]	Ghana	CT	350	M	35.01 ± 1.92	43.53 ± 1.78	80.52 ± 4.66	Microseme
				F	35.14 ± 1.69	42.81 ± 1.58	82.15 ± 3.83	Microseme
				AV			81.22 ± 4.22	Microseme
Mani., *et al.* [11]	India	CT	100	M	23.38 ± 2.46	29.80 ± 1.55		
				F	21.32 ± 2.15	26.47 ± 2.03		
Ramamoothy., *et al.* [20]	India	CT	70	M	35.8 ± 3.2	42.1 ± 2.0		
				F	34.7 ± 2.1	39.6 ± 1.9		
Antunes., *et al.* [21]	Brazil	CT	100	M	34.36 ± 3.25	34.78 ± 2.92		
				F	33.98 ± 2.66	33.74 ± 1.64		
				AV	34.16 ± 3.07	34.34 ± 2.62		
Current Study	Nigeria	CT		M	39.23 ± 3.03	36.79 ± 2.58	106.6 ± 7.665	Megaseme
				F	36.15 ± 2.80	34.30 ± 3.40	105.4 ± 8.004	Megaseme
				AV	37.69 ± 2.99	35.77 ± 3.18	105.4 ± 7.825	Megaseme

Table 2: Mean orbital measurements and orbital classification in various population groups.

CT: Computed Tomography; AV: Average

Author	Country	Method	N	IOD (cm)		BOD (cm)	
				Male	Female	Male	Female
Pereira., *et al.* [12]	Brazil	CT	107	2.07	3.14	9.76	9.30
Ramamoothy., *et al.* [20]	India	CT	70	1.50	1.20	9.76	9.14
Mani., *et al.* [11]	India	CT	100	2.25	1.98	7.83	7.44
Antunes., *et al.* [21]	Brazil	CT	100	3.32	3.32	9.13	8.90
Ozdici., *et al.* [5]	Turkey	CT	302	2.51	2.52	9.98	9.54
El-Farouny., *et al.* [17]	Egypt	CT	89	2.35	2.27		
Current study	Nigeria	CT	336	3.03	2.86	10.32	9.66

Table 3: The mean interorbital and biorbital distances in different study populations.

CT: Computed Tomography; PA: Posterior Anterior; IOD: Interorbital Distance; BOD: Biorbital Distance

Morphometric parameters	Age-groups (Years)								P value
	20-29	30-39	40-49	50-59	60-69	70-79	80-89	90-99	
Orbital width (cm)	3.594	3.585	3.568	3.579	3.557	3.535	3.527	3.520	0.351
Orbital height (cm)	3.801	3.796	3.787	3.795	3.759	3.738	3.733	3.730	0.526
Orbital index	105.76	105.88	106.13	106.03	105.67	105.74	105.82	105.96	0.743
BOD (cm)	10.340	9.961	10.209	10.397	10.081	9.594	9.729	9.891	0.399
IOD (cm)	2.730	2.862	3.040	2.782	2.928	3.090	3.014	3.107	0.264

Table 4: Orbital measurements in the various age-groups

IOD: Interorbital Distance; BOD: Biorbital Distance.

symmetry was observed in 294 (87.5%) skulls while 42 (12.5%) skulls had asymmetrical orbits. The side and gender differences in the distribution of these orbital types were statistically significant ($p < 0.05$) (Table 5).

In both males and females, there was no significant correlation between age and any of the measured variables ($P > 0.05$). The orbital width in both males and females showed a significant weak positive correlation with the orbital height, IOD and BOD (0 < r <

Type of Orbit	Frequency (%)				
	Side		Gender		
	Left	Right	Male	Female	General population
Megaseme (> 89)	197 (58.6)	239 (71.1)	293 (73.6)	143 (52.2)	436 (64.9)
Mesoseme (89-83)	83 (24.7)	56 (16.7)	62 (15.6)	77 (28.1)	139 (20.7)
Microseme (< 83)	56 (16.7)	41 (12.2)	43 (10.8)	54 (19.7)	97 (14.4)
Total	336 (100.0)	336 (100.0)	398(100.0)	274 (100.0)	672 (100.0)
P value	0.027*		0.041*		

Table 5: Side and Gender distribution of the orbit types0

*P value considered significant at < 0.05.

0.5) ($p < 0.05$). The BOD showed a weak positive correlation with the IOD ($0 < r < 0.5$), however, this was only significant in the males (Tables 6 and 7). The right orbital height and width showed significant weak positive correlation with the corresponding variables on the left orbit in both sex groups ($0 < r < 0.5$, $p < 0.05$) (Table 8).

From the univariate discriminant function analysis, the calculated group centroids and sectioning points as well as the prediction accuracies of each metric parameter are shown on Table 9 and 10 respectively. The width of the left orbit was the most sex discriminating variable (259, 77.1%) followed by the IOD (257, 76.5%) and

Metric variable		Age	Orbital width	Orbital Height	BOD	IOD
Age	r value	1	-0.156	-0.024	-0.349	0.286
	Sig. (2 tailed)		0.624	0.352	0.471	0.269
Orbital width	r value	-0.156	1	0.260*	0.328*	0.275*
	Sig. (2-tailed)	0.624		0.001	0.011	0.042
Orbital Height	r value	-0.024	0.260*	1	0.094	0.020
	Sig. (2-tailed)	0.352	0.001		0.085	0.712
BOD	r value	-0.349	0.328*	0.094	1	0.239*
	Sig. (2-tailed)	0.471	0.011	0.085		0.001
IOD	r value	0.286	0.275*	0.020	0.239*	1
	Sig. (2-tailed)	0.269	0.042	0.712	0.001	

Table 6: Correlation between the metric parameters of the orbit in males.

r: Pearson's correlation coefficient, *P value considered significant at < 0.05, IOD: Interorbital Distance, BOD: Biorbital Distance

Metric variable		Age	Orbital width	Orbital Height	BOD	IOD
Age	r value	1	-0.234	-0.115	-0.351	0.245
	Sig. (2 tailed)		0.514	0.097	0.325	0.867
Orbital width	r value	-0.234	1	0.185*	0.413*	0.296*
	Sig. (2-tailed)	0.514		0.001	0.028	0.001
Orbital Height	r value	-0.115	0.185*	1	0.173	0.258
	Sig. (2-tailed)	0.097	0.001		0.075	0.175
BOD	r value	-0.351	0.413*	0.173	1	0.164
	Sig. (2-tailed)	0.325	0.028	0.075		0.241
IOD	r value	0.245	0.296*	0.258	0.164	1
	Sig. (2-tailed)	0.867	0.001	0.175	0.241	

Table 7: Correlation between the metric parameters of the orbit in females

r: Pearson's correlation coefficient, *P value considered significant at < 0.05, IOD: Interorbital Distance; BOD: Biorbital Distance

Metric parameters	Males		Females	
	r value	P value	r value	P value
Right orbital height and left orbital height	0.255	0.034*	0.173	0.024*
Right orbital width and left orbital width	0.369	0.008*	0.154	0.043*

Table 8: Correlation between the metric variables of the right and left orbits.

r- Pearson's correlation coefficient *P value considered significant at < 0.05.

the height of the left orbit (256, 76.2%). From the calculated canonical coefficients and constants in the multivariate discriminant function analysis, the following equation was derived; Discriminant Function Coefficient (D0) = – 19.741* (Constant) + 0.520* Right orbital width + 2.147*Left orbital width + 0.082 * Right orbital height + 0.644* Left orbital height + 0.277* BOD + 1.558 * IOD. The centroids obtained when the metric parameters were substituted into the equation were further used to determine the sectioning point (-0.112) which was used as a cutoff for gender grouping. From this multivariate analysis, the overall accuracy of sex prediction was 79.2% (266) with a higher probability of correctly predicting males (170, 85.4%) than females (96, 70.1%) (Table 11).

Metric parameter	Constant	Canonical Coefficients	Group Centroids		Sectioning points
			Male	Female	
Right orbital width	-11.118	3.110	0.304	-0.441	-0.069
Left orbital width	-13.526	3.778	0.397	-0.576	-0.090
Right orbital height	-12.777	3.274	0.186	-0.271	-0.043
Left orbital height	-13.736	3.571	0.142	-0.207	-0.033
BOD	-10.961	1.090	0.296	-0.429	-0.067
IOD	-10.223	3.454	0.249	-0.362	-0.057

Table 9: Univariate discriminant function analysis of orbital measurements

IOD: Interorbital Distance; BOD: Biorbital Distance

Parameter	Original Accuracy			Accuracy after cross validation		
	Male (%)	Female (%)	Overall (%)	Male (%)	Female (%)	Overall (%)
Right orbital width	165 (82.9)	87 (63.5)	252 (75)	164 (82.4)	87 (63.5)	251 (74.7)
Left orbital width	167 (83.9)	92 (67.2)	259 (77.1)	166 (83.4)	91 (66.4)	257 (76.5)
Right orbital height	158 (79.4)	80 (58.4)	238 (70.8)	155 (77.9)	80 (58.4)	235 (69.9)
Left orbital height	166 (83.4)	90 (65.7)	256 (76.2)	164 (82.4)	90 (65.7)	254 (75.6)
IOD	166 (83.4)	91 (66.4)	257 (76.5)	166 (83.4)	91 (64.4)	257 (76.5)
BOD	159 (79.9)	84 (61.3)	243 (72.3)	159 (79.9)	84 (61.3)	243 (72.3)

Table 10: Prediction rates from univariate analysis of orbital measurements.

Metric parameter	Unstandardized coefficients	Group centroids		Sectioning point	Prediction accuracy (%)		
		Male	Female		Overall	Males	Females
Right orbital width	0.520	0.494	-0.718	-0.112	266 (79.2)	170 (85.4)	96 (70.1)
Left orbital width	2.147						
Right orbital height	0.082						
Left orbital height	0.644						
BOD	0.277						
IOD	1.558						
Constant	-19.741						

Table 11: Multivariate discriminant function analysis of orbital measurements.

Wilks Lambda 0.248, Eigen value 2.491, IOD: Interorbital Distance; BOD: Biorbital Distance

Discussion

The mean orbital height in this study (3.769 cm) was greater than the width (3.577 cm). This corresponded to the findings of Bankole., *et al*. who measured the dimensions of the orbits on radiographs of patients from the Ikwere and Kalabari ethnic groups in Nigeria [19]. Conversely, previous studies in Nigeria, India, Ghana and Iran documented larger orbital width than height (Table 2) [1,9,10,16]. The current study documented higher BOD than previously documented reports while the mean IOD was within the range in literature (1.20-3.32 cm) (Table 3) [12,17,20,21]. The ratio of IOD to BOD was 0.3 in both males and females, suggesting that the IOD can be estimated from BOD (30% of the BOD) and vice versa. On the contrary, Patra., *et al.* documented that the IOD was averagely 25% of BOD (< 20% and > 20% of BOD in males and females respectively) [2]. This discrepancy could be attributed to the larger mean orbital widths that occupied a greater proportion of the BOD than the IOD in the Indians studied by Patra., *et al.* compared to the Nigerians herein [2]. The IOD is important in the diagnosis of hypotelorism (short IOD) and hypertelorism (long IOD). Hypotelorism is associated with holoprosencephaly and craniosynostosis while hypertelorism is associated with craniofacial deformities such as craniofacial dysplasias, clefts, and Crouzon syndrome [8]. These conditions require corrective cosmetic surgeries which should consider the normal IOD values.

Variations of the orbital dimensions in literature are attributed to differences in race, ethnicity, genetics, geographical and climatic factors [9,10,14]. Additionally, the studies in literature have used different sample sizes and composition (age and gender distribution), different methods of measurements; using dry skull, X-ray or CT scan images and volunteers besides different definitions and landmarks for the metric variables, hence the discrepancies in the findings [3,8,20]. Larger orbital width than height corresponding to smaller OI has been reported in various study populations [9,10,16]. The OI in the current study was consistent with the findings of Bankole., *et al*. and lower than reports of Ozdici., *et al*. who similarly observed larger orbital height than width [5,19]. According to Fatima., *et al.* people with larger OI have narrower faces [7].

Consistent with previously documented reports, significantly larger orbital measurements were observed in males than females [11,13,16,21]. Moreover, the megaseme orbits showed significantly higher prevalence in males than in females. In contrast, female subjects had significantly higher OI in Ghana and Sri Lanka and longer IOD in Turkey [1,5,14]. According to Mani., *et al*. and Antunes., *et al*. this sexual dimorphism implies that, in the absence of long bones, as in cases of fragmented skeletal relics, the preserved orbits may be used for sex determination [11,21]. On the contrary, no sexual dimorphism was observed in the radiographic and direct skull orbital measurements in India and Kenya correspondingly [2,15]. Hence, these variables are not warranted in sexing the crania in these populations. Sexual dimorphism in the skeletal system is mainly due to genetic composition and hormonal differences between sexes that drive bone growth and development at different rates [6]. Secreted androgens result in secondary sexual characteristics with associated bone thickening due to higher periosteal bone formation in males [4,22]. Furthermore, sexual dimorphism of tissues is influenced by stress, socioeconomic status and diet [17]. It is therefore important to consider gender while estimating the dimensions of the orbits.

Consistent with Khademi and Bayat, the right orbit had significantly larger dimensions than the left in both sex groups [10]. Additionally, the megaseme orbits was significantly more prevalent on the right than on the left. On the contrary, some studies documented no significant side differences in the orbital variables [5,13,17,23]. Amjad., *et al*. documented significant side differences in the orbital height in India [9]. The OI of males in this study showed significant side difference which was consistent with Amjad., *et al*. [9]. The orbital classification using OI also revealed the presence of orbital asymmetry (12.5%) contrary to the findings by Khan., *et al.* [4]. Commonly, the right orbit is larger than the left due to the differential growth of the brain with lateral dominancy of the left cerebral hemisphere over the right hemisphere subsequently causing asymmetric growth of the orbits [10,17]. This should be considered during surgical correction of the bony orbit for efficient structural disposition of the visual apparatus [2].

All the measurements assessed in this study neither showed significant differences in the various age groups nor significant correlation with age in both genders. Similarly, Patra., *et al.* reported no association between age groups and IOD or BOD [2]. In Turkey, the height of the orbits showed a positive significant correlation with age while the width and IOD showed a negative significant correlation with age [5]. According to Pereira., *et al.* orbits increase in size up to 60 years or older and thereafter they decrease in size [12]. Khan., *et al.* documented that the width of the orbits increases more with age than the height [4]. On the contrary, a decrease in orbital parameters with age was reported by Khademi and Bayat [10]. Our findings differed from previous reports due to the differences in race, genetics, and the variations in the age groupings and sample sizes of each group used in the studies.

In the prenatal period, the transformation of the facial skeleton into adult form is genetically regulated [6]. There is a little change of the interorbital region after birth followed by the continuous growth of the lateral orbital wall throughout childhood hence the IOD is narrow in children, causing an apparent squint. The growth of frontal and ethmoid sinuses with age increases the IOD. At 10-19 years the orbits are round and later change to elliptical and rectangular, thus larger in adults [2]. The changes in the orbital size with age have been ascribed to the different growth of the facial bones, environmental and epigenetic factors such as climate, nutritional status, cultural differences, hormones and masticatory patterns [2,6,12]. Congruent with the findings of Patra., *et al.* the peak OI was observed in the 40-49 years age group [2]. However, in the aforementioned study, the peak OI in females occurred earlier (10-19 years) than in males (40-49 years) due to the earlier metamorphic changes in the orbital bones in females. Among the Igbos of Nigeria, the peak OI was earlier (30-39 years) than the peak herein possibly due to the differences in the gender composition in the age groups [23]. A decline in the OI with advancing age could be genetically determined or may be due to continuous cortical bone resorption and remodeling, with subsequent volume loss at the midface region [2].

Consistent with Bankole., *et al.* the average OI in this study revealed the presence of megaseme orbit in both sex groups [19]. Conversely, microseme orbits have been documented in Nigeria and Ghana while mesoseme orbits were reported in Kenya and Iran [1,10,15,16]. The males in Kenya and Sri Lanka had smaller (microseme) orbits than their female counterparts (mesoseme) [14,15].

The significant positive association between orbital width and BOD or IOD implies that the transverse growth of the orbits is associated with the concurrent expansion of the IOD and BOD. Furthermore, we observed significant positive association between corresponding variables bilaterally and between the orbital height and width. On the contrary, Khademi and Bayat reported a significant negative correlation between the height and width of the orbits [10]. The significant association between metric parameters suggests that one can be used to estimate the other with some degree of accuracy, hence useful in forensic investigations and surgical planning.

The best sex discriminating variable in this study was the width of the left orbit (77.1%). From the multivariate analysis, the overall accuracy for sex prediction was 79.2% (85.4% males, 70.1% females). Collectively, all the metric parameters in this study provide high sex prediction accuracy. Moreover, these variables may be combined with other sexually dimorphic measurements for better accuracy. In India, the orbital breadth and IOD had an accuracy of 74.3% and 70% correspondingly [20]. In another Indian study, the overall accuracy of sex prediction using the width and height of the orbits bilaterally was 81.8% (87.5% males and 66.7% females) [3]. According to Mani., *et al.* the IOD was the best sex discriminating variable (63%) and the overall sex prediction rate was 92% (96% males, 88% females) [11]. In Brazil, the overall probability for correct sex allocation using the OI was 65.6% (66.3% females, 65% males) hence, it was suggested that this variable can only be used as an auxiliary method for sex estimation in the studied population [13]. The discrepancies in the accuracies in literature have been ascribed to the variations in age, ethnicity, sample size, method of measurement, the varying definition of parameters, metric variables included in DFA, and the statistical tools used in the different studies [11,17].

The limitation of this study was the small sample size used. This was due to the retrospective nature of the study and the adoption of the purposive sampling technique. The CT images utilized were from a single hospital in Delta State Nigeria and limited to only 5 years duration.

Conclusion

The dimensions of the orbits showed significant sexual dimorphism and moderately high accuracy in sex prediction. Therefore, the orbits could possibly be used as an auxiliary method for sex determination in our studied population. The significant association between the orbital measurements may be used in planning orbital surgery.

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Conflict of Interest

The authors have none to declare.

Bibliography

1. Botwe BO., *et al*. "Radiologic evaluation of orbital index among Ghanaians using CT scan". *Journal of Physiological Anthropology* 36 (2017): 29.
2. Patra A., *et al.* "Morphological and morphometric analysis of the orbital aperture and their correlation with age and gender: A retrospective digital radiographic study". *Cureus* 13.9 (2021): e17739.
3. Ghosh R., *et al*. "Sexual dimorphism in right and left orbital fossa measurements from adult human skulls from an eastern Indian population". *Journal of Forensic Science and Medicine* 5.4 (2019): 173-176.
4. Khan Z., *et al*. "An anatomical study of orbital dimensions and its utility in orbital reconstructive surgery". *Oncology and Radiotherapy* 15.3 (2021): 1-9.
5. Ozdikici M., *et al*. "Assessment of the orbital structures using computed tomography in healthy adults". *Nigerian Journal of Clinical Practice* 24.4 (2021): 561-568.
6. Shukla A., *et al*. "Measurement of orbital dimensions (orbital height, breadth and length of superior orbital fissure) using Dry Skulls". *Delhi Journal of Ophthalmology* 21.1 (2020) 41-44.
7. Fatima PS., et al. "Morphometry of The Orbital Region in Dry Skull and CT images". *International Journal of Health and Clinical Research* 5.2 (2022): 344-346.
8. Gupta V., et al. "Computed tomography imaging-based normative orbital measurement in Indian population". *Indian Journal of Ophthalmology* 67.5 (2019): 659-663.
9. Amjad S., et al. "Orbital dimensions of Maharashtrian population a direct measurement study using dry skulls". *International Dental Journal of Student Research* 7.4 (2019): 103-106.
10. Khademi Z and Bayat P. "Computed tomographic measurements of orbital entrance dimensions in relation to age and gender in a sample of healthy Iranian population". *Journal of Current Ophthalmology* 28 (2016): 81-84.
11. Mani SM., *et al.* "Evaluation of orbital morphometry using 3D computed tomographic images in biological sex determination: A retrospective study". *Journal of Indian Academy of Oral Medicine and Radiology* 32.40 (2020): 390-395.
12. Pereira AM., *et al.* "Orbital cavity evaluation in a Brazilian population". *Journal of Oral and Maxillofacial Radiology* 7.1 (2019): 1-5.
13. Fernandes LC., *et al.* "Craniometric study of the Orbital Index in Brazilian skulls". *Revista Gaúcha de Odontologia* 69 (2021): e2021013.
14. Lal N., *et al.* "Orbital indices in a modern Sinhalese Sri Lankan population". *International Journal of Experimental and Clinical Anatomy* 10.3 (2016): 205-210.
15. Munguti J., *et al.* "Sex differences in the cranial and orbital indices for a black Kenyan population". *International Journal of Medicine and Medical Sciences* 5.2 (2013): 81-84.
16. Ebeye OA and Otikpo O. "Orbital index in Urhobos of Nigeria". *IOSR Journal of Dental and Medical Sciences* 8.2 (2013): 51-53.
17. El-Farouny RH., *et al.* "Morphometric evaluation of piriform and orbital aperture in sex discrimination by using computed tomography in Egyptian population". *Egyptian Journal of Forensic Science and Applied Toxicology* 21.1 (2021): 1-10.
18. Ominde BS and Igbigbi PS. "A retrospective study to evaluate the morphometry of the foramen magnum and its role in forensic science in a Nigerian population of Delta State". *Journal of Forensic Science and Medicine* 20 (2021): 20-21.
19. Bankole L, *et al.* "Radiological Assessment of Orbital Dimensions of the Kalabaris and Ikwerres of Rivers State, Nigeria". *African Journal of Biomedical Research* 15.3 (2012): 197-200.
20. Ramamoorthy B., *et al.* "Discriminant function analysis of craniometrics traits for sexual dimorphism and its implication in forensic anthropology". *Journal of Anatomical Society of India* 68.4 (2020): 260-268.
21. Antunes AA., *et al*. "Can orbital cavity be used to estimate stature in human identification?" *Advances in Anthropology* 11 (2021): 1-12.

22. Ominde BS and Igbigbi PS. "Morphometry of the occipital condyles in adult Nigerians". *Online Journal of Health and Allied Sciences* 20.4 (2021): 10.

23. Ezeuko V and Om'Inoabohs F. "Radiologic evaluation of the orbital index among the Igbo ethnic group of Nigeria". *European Journal of Anatomy* 19.1 (2015): 9-14.Botwe BO., *et al*. "Radiologic evaluation of orbital index among Ghanaians using CT scan". *Journal of Physiological Anthropology* 36 (2017): 29.

24. Patra A., *et al.* "Morphological and morphometric analysis of the orbital aperture and their correlation with age and gender: A retrospective digital radiographic study". *Cureus* 13.9 (2021): e17739.

25. Ghosh R., *et al*. "Sexual dimorphism in right and left orbital fossa measurements from adult human skulls from an eastern Indian population". *Journal of Forensic Science and Medicine* 5.4 (2019): 173-176.

26. Khan Z., *et al*. "An anatomical study of orbital dimensions and its utility in orbital reconstructive surgery". *Oncology and Radiotherapy* 15.3 (2021): 1-9.

27. Ozdikici M., *et al*. "Assessment of the orbital structures using computed tomography in healthy adults". *Nigerian Journal of Clinical Practice* 24.4 (2021): 561-568.

28. Shukla A., *et al*. "Measurement of orbital dimensions (orbital height, breadth and length of superior orbital fissure) using Dry Skulls". *Delhi Journal of Ophthalmology* 21.1 (2020) 41-44.

29. Fatima PS., et al. "Morphometry of The Orbital Region in Dry Skull and CT images". *International Journal of Health and Clinical Research* 5.2 (2022): 344-346.

30. Gupta V., et al. "Computed tomography imaging-based normative orbital measurement in Indian population". *Indian Journal of Ophthalmology* 67.5 (2019): 659-663.

31. Amjad S., et al. "Orbital dimensions of Maharashtrian population a direct measurement study using dry skulls". *International Dental Journal of Student Research* 7.4 (2019): 103-106.

32. Khademi Z and Bayat P. "Computed tomographic measurements of orbital entrance dimensions in relation to age and gender in a sample of healthy Iranian population". *Journal of Current Ophthalmology* 28 (2016): 81-84.

33. Mani SM., *et al.* "Evaluation of orbital morphometry using 3D computed tomographic images in biological sex determination: A retrospective study". *Journal of Indian Academy of Oral Medicine and Radiology* 32.40 (2020): 390-395.

34. Pereira AM., *et al.* "Orbital cavity evaluation in a Brazilian population". *Journal of Oral and Maxillofacial Radiology* 7.1 (2019): 1-5.

35. Fernandes LC., *et al.* "Craniometric study of the Orbital Index in Brazilian skulls". *Revista Gaúcha de Odontologia* 69 (2021): e2021013.

36. Lal N., *et al.* "Orbital indices in a modern Sinhalese Sri Lankan population". *International Journal of Experimental and Clinical Anatomy* 10.3 (2016): 205-210.

37. Munguti J., *et al.* "Sex differences in the cranial and orbital indices for a black Kenyan population". *International Journal of Medicine and Medical Sciences* 5.2 (2013): 81-84.

38. Ebeye OA and Otikpo O. "Orbital index in Urhobos of Nigeria". *IOSR Journal of Dental and Medical Sciences* 8.2 (2013): 51-53.

39. El-Farouny RH., *et al.* "Morphometric evaluation of piriform and orbital aperture in sex discrimination by using computed tomography in Egyptian population". *Egyptian Journal of Forensic Science and Applied Toxicology* 21.1 (2021): 1-10.

40. Ominde BS and Igbigbi PS. "A retrospective study to evaluate the morphometry of the foramen magnum and its role in forensic science in a Nigerian population of Delta State". *Journal of Forensic Science and Medicine* 20 (2021): 20-21.

41. Bankole L, *et al.* "Radiological Assessment of Orbital Dimensions of the Kalabaris and Ikwerres of Rivers State, Nigeria". *African Journal of Biomedical Research* 15.3 (2012): 197-200.

42. Ramamoorthy B., *et al.* "Discriminant function analysis of craniometrics traits for sexual dimorphism and its implication in forensic anthropology". *Journal of Anatomical Society of India* 68.4 (2020): 260-268.

43. Antunes AA., *et al*. "Can orbital cavity be used to estimate stature in human identification?" *Advances in Anthropology* 11 (2021): 1-12.