Emerging Frontiers in Translational
Biomedicine and Health Sciences

E-mail: emergingfrontier.tbhs@gmail.com

Original Article

Morphometric Assessment of the Clivus using Computed Tomography in Adult Nigerians Visiting a Private Health Care Facility in Delta State

Beryl Shitandi Ominde[1], Oghenetejiri Denise Ogholoh[2], Sarah Isioma Sunday[3], Ogheneyole Jeremiah[3*], Mamerhi Taniyohwo Enaohwo[3], Patrick Sunday Igbigbi[3]

[1]*Department of Biomedical Sciences, Aga Khan University, Nairobi, Kenya*
[2]*Department of Radiology, Delta State University Teaching Hospital, Oghara, Nigeria*
[3]*Department of Human Anatomy and Cell Biology, Delta State University, Abraka, Nigeria*

*Correspondence: jeremiahjoel40@gmail.com | +2348139349499 | https://orcid.org/0009-0007-9628-6937

Citation: Ominde, B.S.; Ogholoh, O.D.; Sunday, S.I.; Jeremiah, O.; Enaohwo, M.T.; Igbigbi. P.S. Morphometric Assessment of the Clivus using Computed Tomography in Adult Nigerians Visiting a Private Health Care Facility in Delta State. *Emerg. Front. Transl. Biomed. Health Sci.* **2026**, 2(1): 51-60

Academic Editor(s): Dr. B.C Nwogueze

Received: 28th April, 2026.
Revised: 8th June, 2026.
Accepted: 29th June, 2026.
Published: 3rd July, 2026.

ISSN (Online): 3141 -3552
ISSN (Print): 3141 -3560

Abstract:

Background: The management of clival pathologies requires accurate morphometric assessment of the clivus to facilitate preoperative planning and inform the design of population-specific implants. The clival index provides valuable insight into clival morphology, an important parameter in skull base surgery. Clival morphometry is also useful in the forensic identification of unknown skeletal remains. This study aimed to evaluate the dimensions of the clivus and determine their variations according to age and sex in a Nigerian population.

Methods: This retrospective cross-sectional study evaluated clival dimensions using 230 cranial computed tomography (CT) images from 115 males and 115 females aged 20–80 years, retrieved from the radiological database of a private hospital in Delta State, Nigeria. Access to the database was granted following approval by a University's Ethics Committee. Data were analyzed using the Statistical Package for the Social Sciences (IBM SPSS Statistics), version 27. The independent-samples *t*-test and one-way analysis of variance (ANOVA) were used to compare mean values between sex and age groups, respectively. Pearson's correlation analysis was performed to assess the relationships between variables. Statistical significance was set at $p < 0.05$.

Results: Clival length and width exhibited significant sexual dimorphism, with males demonstrating larger dimensions than females ($p < 0.05$). In contrast, age was not significantly correlated with either clival length or width. A strong positive correlation was observed between clival length and width ($p < 0.05$).

Conclusion: This study provides population-specific baseline morphometric data that may support preoperative planning for craniovertebral junction (CVJ) procedures and contribute to the development of clival implants and fixation devices tailored to the population of Delta State, Nigeria. The observed sexual dimorphism also suggests that clival morphometry may serve as a useful adjunct skeletal marker for forensic sex estimation.

Keywords: *Clivus; Morphometry; Brain; Computed tomography; Neurosurgery*

1. Introduction

The craniovertebral junction (CVJ) is a complex anatomical region that protects vital neurovascular structures while permitting a wide range of head and neck movements. A thorough understanding of CVJ anatomy is essential for comprehending the pathophysiology of related disorders and for planning their surgical management [1]. Located centrally at the skull base, the clivus extends between the foramen magnum and the dorsum sellae [2]. It consists of superior and inferior portions derived from the sphenoid bone and the basiocciput, respectively [3]. Anteriorly, the clivus is related to the sphenoid sinus, whereas posteriorly it forms the anterior wall of the premedullary and prepontine cisterns. Laterally, it is bounded by the petro-occipital fissures [4,5].

The developing brain plays an important role in regulating the endochondral ossification of the clivus [6]. Fusion of the basioccipital–exoccipital synchondrosis begins around the third year of life and is typically completed by approximately 25 years of age [7]. Although the clivus reaches its definitive dimensions by about 11 years of age and remains relatively stable thereafter [5], postnatal elongation continues as the spheno-occipital synchondrosis develops, with peak activity occurring between 10 and 13 years of age. Closure of this synchondrosis generally occurs later in males than in females [3]. Disruption of this developmental process may result in a shortened or hypoplastic clivus [8]. Reduced clival length has been implicated in Chiari malformation, where it contributes to cerebellar tonsillar herniation and overcrowding of the posterior cranial fossa [4,9]. Similarly, clival shortening in basilar invagination is associated with platybasia and underdevelopment of the basiocciput [8].

The clinical importance of the clivus is underscored by its close anatomical relationship with critical structures, including the abducens nerve, sella turcica, vertebral venous plexus, and the brainstem, which contains vital autonomic centres [10,11]. Various pathological conditions involving the clivus, such as meningiomas, pituitary adenomas, giant cell tumours, fibrous dysplasia, chondromas, metastatic lesions, and traumatic injuries, often require complex surgical reconstruction. Successful surgical planning depends on accurate clival morphometry, which also facilitates the design of population-specific implants and fixation devices [2,5,12]. Because clival lesions frequently present with non-specific clinical symptoms, imaging plays a crucial role in their diagnosis and evaluation [2]. Computed tomography (CT) provides excellent three-dimensional visualization of both cortical and cancellous bone, allowing precise morphometric assessment of the clivus. In addition, cone-beam CT (CBCT) offers rapid image acquisition while delivering relatively low radiation doses [7]. Accurate CT-based morphometric evaluation assists surgeons in selecting safe operative corridors and minimizing the risk of intraoperative complications [13].

Beyond its clinical applications, the clivus has considerable forensic significance. Owing to its dense structure and resistance to postmortem degradation, it remains relatively well preserved even in fragmented skeletal remains recovered from mass disasters [5,7,11]. Consequently, clival morphometry can contribute to the construction of an individual's biological profile, particularly in the estimation of age and sex [7,10].

Several factors influence variations in clival morphology, including genetics, developmental processes, age, stature, and sex [2,9,14]. Despite the increasing use of CT for evaluating the CVJ in Africa, population-specific morphometric data on the clivus remain limited. Morphometric values derived from Asian and Western populations may not be directly applicable to African populations because of documented ethnic and geographical differences [1,14]. To the best of our knowledge, clival morphometric data have been reported for Northern Nigeria [5]; however, corresponding data from Southern Nigeria remain scarce. This lack of region-specific information represents an important knowledge gap, particularly given the potential influence of ethnic and geographical diversity on cranial morphology [5]. Reliance on morphometric data from other populations may result in inaccurate anatomical assessment, suboptimal surgical planning, and limitations in the design of population-appropriate reconstructive implants. Therefore, this study was conducted among Southern Nigerians who underwent cranial CT examinations in Delta State. The aim was to determine the morphometric characteristics of the clivus and evaluate their variations according to age and sex.

2. Materials & Methods

This descriptive cross-sectional study retrospectively evaluated cranial images archived in the radiological database of a private hospital in Delta State, Nigeria. Ethical approval was obtained from the Ethical Board, Faculty of Basic Medical Sciences, Delta State Univeristy, Abraka, before commencement of the study (Approval No.: RBC/FBMC/DELSU/25/877). A convenience sampling technique was employed to select CT scans from 230 patients (115 males and 115 females) aged 20 years and above to ensure the inclusion of individuals with fully developed clival morphology [5]. Only high-quality, radiologically adequate CT scans acquired over a two-year period (1st January 2023 to 30th January 2025) were included. CT scans demonstrating poor visualization of the clivus, CVJ deformities, posterior cranial fossa pathologies, skull base trauma, previous surgery, or congenital anomalies such as Chiari malformation and basilar invagination were excluded. A formal sample size calculation was not performed because all eligible CT images archived in the radiological database during the study period were included. Demographic information, including age and sex, was extracted from the electronic records associated with each CT scan. To investigate possible age-related variations in clival morphology, participants were stratified into 10-year age groups.

All examinations had been performed using a 64-slice Aquilion CT scanner (Toshiba, Japan) with the following acquisition parameters: 0.5-mm slice thickness, 120 kV tube voltage, 120–250 mA tube current, 0.3-mm interslice spacing, and bone-window settings (window level: 300 Hounsfield units [HU]; window width: 2500 HU). During image acquisition, patients were positioned supine with the head aligned such that the midsagittal plane was maintained vertically by positioning the examination table parallel to the line extending from the anterior nasal spine to the hard palate.

Image analysis was performed on a dedicated Picture Archiving and Communication System (PACS) workstation using axial, coronal, and sagittal multiplanar reconstructed images. Clival measurements were obtained using the electronic caliper integrated into the PACS software. To minimize observer variability, all measurements were performed by a single experienced investigator. Clival length was defined as the maximum craniocaudal distance from the superior tip of the dorsum sellae to the most inferior point of the basion on the midsagittal image (Figure 1). Clival width was measured on the axial image at the inferior aspect of the foramen magnum and defined as the greatest transverse distance across its anterior margin (Figure 2) [2,5].

To evaluate measurement reproducibility, the same investigator repeated the measurements on 20% of the selected CT images after an interval of two weeks. Intra-observer reliability was assessed using the intraclass correlation coefficient (ICC). The measurements demonstrated good repeatability, with ICC values of 0.772 (95% confidence interval [CI]: 0.65–0.86) for clival length and 0.767 (95% CI: 0.68–0.81) for clival width.

Statistical analysis was performed using IBM Statistical Package for Social Sciences (SPSS) Statistics version 27 (IBM Corp., Armonk, NY, USA). Data normality was assessed using the Shapiro–Wilk test, which confirmed a normal distribution of the continuous variables. Consequently, parametric statistical tests were employed throughout the analysis. Continuous variables were summarized as mean ± standard deviation (SD), and statistical significance was set at $p < 0.05$. The clival index was calculated as the ratio of clival length to clival width [15].

Sex differences in clival measurements were assessed using the independent-samples *t*-test. Effect sizes were calculated using Cohen's *d*, with corresponding 95% confidence intervals. Differences in clival dimensions across age groups were evaluated using one-way analysis of variance (ANOVA). Analysis of covariance (ANCOVA) was performed to examine the influence of age on clival dimensions while controlling for sex, and the magnitude of the effect was expressed as partial eta squared (ηp^2). Multivariate analysis of variance (MANOVA) was used to assess the multivariate effect of sex on clival length and width simultaneously, with Wilks' lambda serving as the test statistic. Pearson's correlation coefficient was used to evaluate the relationships among age, clival length, and clival width.

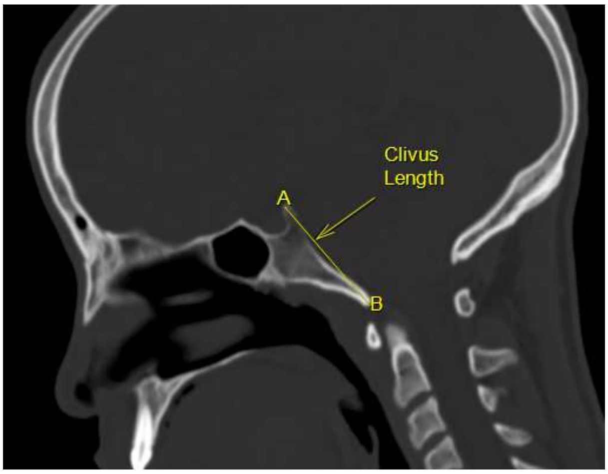

Figure 1: *Measurement of the clivus length on a sagittal cranial CT scan from A to B, where A = upper tip of the dorsum sellae, and B = basion (unit of measurement: centimeters).*

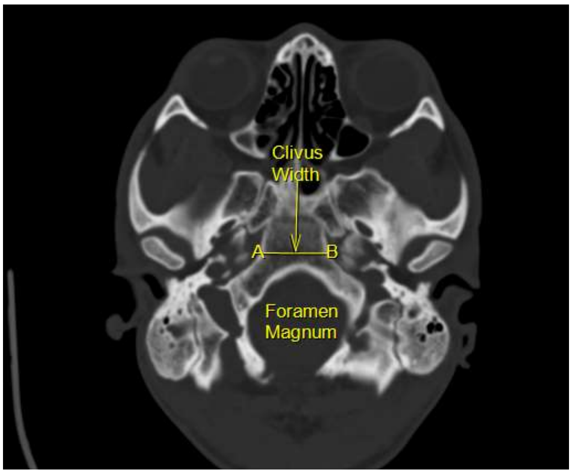

Figure 2: *Measurement of the clivus width on an axial cranial CT scan from A to B. A and B = lateral ends of anterior margin of foramen magnum (unit of measurement: centimeters).*

3. Results

A total of 230 cranial CT images from 230 patients (115 males and 115 females) were evaluated in this study. The overall mean age of the participants was 51.45 ± 16.07 years, with mean ages of 52.50 ± 15.98 years for males and 50.40 ± 16.51 years for females. Participants ranged in age from 20 to 80 years. When stratified into 10-year age groups, the 61–70-year age group had the highest representation (59 participants; 25.7%), whereas the 71–80-year age group had the lowest representation (25 participants; 10.9%) as presented in Table 1.

Table 1. Age and gender composition of the study population

Age Groups (years)	Male N (%)	Female N (%)	Total Population N (%)
20-30	14 (12.2)	19 (16.5)	33 (14.3)
31-40	15 (13.0)	17 (14.8)	32 (13.9)
41-50	22 (19.1)	23 (20.0)	45 (19.6)
51-60	21 (18.3)	15 (13.0)	36 (15.7)
61-70	26 (22.6)	33 (28.7)	59 (25.7)
71-80	17 (14.8)	8 (7.0)	25 (10.9)
Total	115 (100.0)	115 (100.0)	230 (100.0)

Table 2. Descriptive statistics for the clival variables

Morphometric parameters (mm)	Minimum	Maximum	Mean±Std. Deviation
Clivus Length (mm)	34.6	57.7	47.01±3.15
Clivus Width (mm)	31.0	53.2	41.04±3.07
Clivus Index	1.02	1.45	1.15±0.07

Table 3. Shapiro–Wilk test for normality

Morphometric parameters (mm)	Gender	Shapiro–Wilk (p Value)
Clivus Length	*Male*	0.078
	Female	0.072
Clivus Width	*Male*	0.087
	Female	0.084
Clivus Index	*Male*	0.065
	Female	0.059

P-value considered significant at <0.05

Table 4. Gender differences in morphometric parameters of the Clivus

Morphometric parameters		Mean ±SD	p-value	Cohen's d	95% CI *Lower*	95% CI *Upper*
Clivus Length (mm)	*Male*	48.52±2.93	<0.001*	1.09	0.81	1.37
	Female	45.50±2.59				
Clivus Width (mm)	*Male*	42.06±2.99	<0.001*	0.90	0.44	0.97
	Female	40.02±2.81				
Clivus Index	*Male*	1.16±0.08	0.080	0.23	-0.03	0.49
	Female	1.14±0.07				

**P-value considered significant at <0.05, CI= Confidence Interval*

The mean clival length, width, and clival index are presented in Table 2. The Shapiro–Wilk test confirmed that the clival variables were normally distributed ($p >$ 0.05), satisfying the assumption of normality (Table 3). Sex differences in clival morphometric parameters are presented in Table 4. Levene's test indicated homogeneity of variances for both clival length (F = 1.258, p = 0.263) and clival width (F = 1.257, p = 0.263). Independent-samples t-test revealed statistically significant sex differences in both clival length and width (p < 0.001), with males exhibiting significantly greater dimensions than females. The magnitude of these differences was large, with Cohen's d values of 1.09 (95% CI: 0.81–1.37) for clival length and 0.90 (95% CI: 0.44–0.97) for clival width. In contrast, the clival index did not differ significantly between males and females (p = 0.080) (Table 4).

Table 5. Variation of Clivus Morphometric Parameters across Age Groups

Age Group (Years)	Clivus Length (mm)	Clivus Width (mm)	Clivus Index
20-30	47.29±3.05	41.40±3.09	1.15±0.07
31-40	47.33±4.42	41.18±3.97	1.15±0.07
41-50	46.12±2.58	40.59±2.75	1.14±0.07
51-60	47.60±3.41	41.50±3.21	1.15±0.08
61-70	46.54±2.74	40.63±2.76	1.15±0.08
71-80	48.05±2.75	41.51±2.88	1.16±0.09
Total	47.01±3.15	41.04±3.07	1.15±0.07
P value	0.090	0.560	0.890

**P-value considered significant at <0.05*

One-way analysis of variance (ANOVA) revealed no statistically significant differences in clival length, width, or clival index across the 10-year age groups (p > 0.05) (Table 5). The effects of age and sex on clival dimensions were further evaluated using analysis of covariance (ANCOVA), allowing each variable to be assessed while controlling for the influence of the other. The results showed that age had no significant effect on either clival length (p = 0.841, ηp^2 = 0.001) or clival width (p = 0.538, ηp^2 = 0.002). In contrast, sex exerted a highly significant effect on both clival dimensions (p < 0.001), accounting for 23.1% (ηp^2 = 0.231) and 14.2% (ηp^2 = 0.142) of the variance in clival length and width, respectively (Table 6). Neither age nor sex had a statistically significant effect on the clival index (p = 0.572 and p = 0.088, respectively).

.

Table 6. ANCOVA results showing the effect of age and sex on clival length and width

Morphometric parameters	ηp^2 (Age)	Age Effect (p value)	ηp^2 (Sex)	Sex Effect (p value)	95% CI	
					Lower	*Upper*
Clivus Length	0.001	0.841	0.231	<0.001*	2.301	3.745
Clivus Width	0.002	0.538	0.142	<0.001*	1.300	2.816
Clivus Index	0.001	0.572	0.013	0.088	-0.003	0.036

**P-value considered significant at <0.05, CI= Confidence Interval, ηp^2 (partial eta squared) = measure of effect size*

The multivariate effect of sex on clival length and width was assessed using multivariate analysis of variance (MANOVA). The analysis demonstrated a significant multivariate effect of sex on the combined clival measurements (Wilks' Λ = 0.466, $F(2, 227)$ = 34.604, p < 0.001). The effect size was large (partial η^2 = 0.234), indicating that sex accounted for 23.4% of the variance in the combined clival measurements. Pearson's correlation analysis showed weak positive correlations between age and clival length (r = 0.020, p = 0.766), clival width (r = 0.017, p = 0.801), and clival index (r = 0.045, p = 0.499). However, none of these associations was statistically significant (p > 0.05). In contrast, clival length and clival width demonstrated a statistically significant strong positive correlation (r = 0.609, p < 0.001) (Table 7).

Table 7. Correlation between Age and the Morphometric Parameters of the Clivus

Morphometric parameters		Age	Clivus Length (mm)	Clivus Width (mm)	Clivus Index
Age	*r*	1	0.020	0.017	0.045
	P value		0.766	0.801	0.499
Clivus Length (mm)	*r*	0.020	1	0.609**	0.340**
	P value	0.766		<0.001	<0.001
Clivus Width(mm)	*r*	0.017	0.609**	1	-0.536**
	P value	0.801	<0.001		<0.001
Clivus Index	*r*	0.045	0.340**	-0.536**	1
	P value	0.499	<0.001	<0.001	

***Correlation significant at the 2 tailed level, r- Pearson's correlation coefficient*

Table 8: Comparison of clival dimensions in different study populations

Author (Year)	Country	Sample Type		Age Range (years)	Sample Size	Mean Clivus Length (mm)	Mean Clivus Width (mm)	Mean Clivus Index
Chaurasia *et al.*[4]	India, Uttar Pradesh	CBCT	*Male*	6-17	76	43.99	29.22	
			Female		74	41.39	28.52	
Nwotchouang *et al.*[18]	USA	CT	*Females*	Mean 35.9	30	47.3	47.2	
ThiruKumaran[16]	India, Chennai	Dry skull	*Total Population*		30	35.30	24.05	
Abdolmaleki *et al.*[2]	Iran	CBCT	*Male*	≥18	68	45.72	31.32	
			Female		62	41.56	31.49	
Kayacı*et al.*[15]	Turkey	Autopsy skull	*Pediatric*	0-18 months	12	26.92	22.35	1.21
			Adult	16-71	17	40.66	29.96	1.36
Shalini *et al.*[21]	India	CBCT	*Male*	6-70	162	43.03	29.74	
			Female		92	42.15	28.52	
Aliyu *et al.*[5]	Northern Nigeria	CT	*Male*	13-70	75	44.38	30.97	
			Female		43	43.67	31.73	
Makhlouf *et al.*[10]	Libya	CT	*Male*	≥18	96	46.10	34	
			Female		56	44.90	33.73	
Moawad *et al.*[7]	Egypt	CBCT	*Male*	5-60	78	45.59	31.63	
			Female		87	42.09	29.95	
Ojha & Debnath[11]	India, Gujarat	CT	*Male*	≥18	62	42.6	27.1	
			Female		63	39.2	26.7	
Current Study	Delta State Nigeria	CT	*Male*	20-80	115	48.52	42.06	1.16
			Female		115	45.50	40.02	1.14

CT= computed tomography, CBCT= Cone Beam computed tomography

4. Discussion

Clival length and width are important morphometric parameters of the cranial base with significant applications in radiology, orthodontics, neurosurgery, and forensic science [16]. They serve as critical anatomical landmarks during endoscopic skull base surgery; therefore, variations in these dimensions may influence surgical exposure, operative corridors, and trajectories for screw placement [17]. In the present study, the mean clival length and width were 47.00 mm and 41.04 mm, respectively. These values were greater than those previously reported in studies from Northern Nigeria [5], Libya [10], Egypt [7], Iran [2], and several Indian populations [4,11,16]. Conversely, adult female control subjects evaluated in the United States exhibited larger clival dimensions than those observed in the present study [18] (Table 8). The discrepancies in clival dimensions reported across different populations have been attributed to variations in age, genetics, sex, ethnicity, race, stature, and geographical location [2,9,11,14]. Furthermore, methodological differences, including the use of dry skulls, autopsy specimens, or various imaging modalities such as lateral cephalograms, CT, CBCT, and magnetic resonance imaging (MRI), may also account for the observed variations [17,19]. In addition, Nwotchouang *et al.* [18] employed three-dimensional segmentation of the clivus using axial CT images, which may explain the larger measurements reported in their study.

A shortened clivus has been associated with absent or impaired longitudinal growth at the spheno-occipital synchondrosis, a characteristic feature of achondroplasia [2]. Reduced clival length has also been reported in patients with basilar invagination, syndromic craniosynostosis, Chiari I malformation, and atlas assimilation [18,20]. A short clivus may reflect an underdeveloped basiocciput and a reduced posterior cranial fossa volume, thereby limiting the available surgical field and increasing the need for meticulous surgical planning to ensure safe screw placement [17]. In patients with Chiari malformation type I (CM-I), clival length has been shown to reliably distinguish symptomatic from asymptomatic cases. A shortened clivus in symptomatic CM-I is associated with an increased tentorial angle and reduced supraoccipital and basisphenoid lengths, whereas increased clival length has been linked to sleep-related respiratory dysfunction [20].

The mean clival index in the present study (1.15) was lower than the value of 1.36 reported by Kayacı *et al.* [15]. This difference may be attributed to ethnic and genetic factors that influence skull base development. A clival index greater than 1.0 indicates a relatively elongated and narrow clivus, a pattern observed in several populations (Table 8). A higher clival index may also reflect a longer clivus, which could influence the dimensions of available surgical corridors during skull base procedures.

The present study demonstrated significantly greater clival length and width in males than in females, in contrast to findings from Northern Nigeria, where neither parameter exhibited significant sexual dimorphism [5]. However, our findings are consistent with reports from Libya, Egypt, and India [7,10,21]. Similarly, several previous studies have reported significantly greater clival length in males than in females [1,3,11,22,23], although some investigators observed significant sex differences only in clival length but not in clival width [2,4]. The absence of significant sex differences in the clival index observed in the present study may reflect proportional growth of the clivus in both sexes throughout adulthood.

Hormonal and developmental factors play important roles in the establishment of sexual dimorphism in cranial morphology [24]. The larger clival dimensions observed in males may be attributed to the longer duration of skeletal growth and maturation in males. Furthermore, testosterone contributes to skull base development by promoting periosteal bone apposition, which may explain the greater clival width observed after puberty [7,25]. Comparable patterns of sexual dimorphism have also been reported in other skull base structures, including the foramen magnum, occipital condyles, and mastoid process among populations in Delta State, Nigeria [25,26,27].

The demonstrated sexual dimorphism in clival dimensions supports their potential use as adjunct skeletal markers for sex estimation, particularly in forensic investigations involving fragmented or incomplete human remains recovered from mass disasters [5]. However, craniometric standards developed for one population may not be directly applicable to another because of geographical, environmental, genetic, and sociocultural factors that contribute to cranial variation, including altitude, climate, dietary practices, and lifestyle [7]. These findings underscore the need for population-specific morphometric databases to improve the accuracy of both forensic identification and clinical decision-making. From a clinical perspective, knowledge of sexually dimorphic clival dimensions may facilitate the future design of population-specific clival implants and assist surgeons in selecting appropriate screw diameter, length, and trajectory during transclival approaches and internal fixation procedures. The larger clival dimensions observed in males may provide relatively wider surgical corridors, potentially reducing the risk of injury to adjacent neurovascular structures during skull base surgery.

Consistent with a previous report by Abdolmaleki *et al.*, [2] we observed no significant differences in the clival dimensions and clival index across the various age groups possibly due to inclusion of adult skulls. After attaining skeletal maturity, bone changes in size and proportion are minimal and possibly caused by pathological and degenerative processes rather than growth [2,5]. On the contrary, some studies have shown significant variations in the clival dimensions across different age groups and this could have been due to inclusion of pediatric age-groups [3,10,21]. Kayacı *et al.*, [15] documented larger clival index in adults (1.36) than children (1.20) suggesting disproportionate growth of the clivus during development. It is important for surgeons to be aware of the relatively stable adult clival measurements across the lifespan suggesting that the sizing of clival implants and surgical corridors in adults should largely be guided by sex and preoperative radiological evaluation rather than chronological age.

Sex significantly affected the clival variables after adjusting for age. However, age lacked significant effect on the clivus dimensions after controlling for sex. Furthermore, the variances observed after combining the clival length and width were significant, largely explained by sex differences. These findings further emphasize the use of clival dimensions in sex determination of adult skulls within a certain age group but caution their utility in age estimation during forensic investigations. The use of combined measurements of both the clival length and width enhances the accuracy of sex prediction hence improving skeletal profiling [5,11,21]. On the contrary, among northern Nigerians [5], neither age nor sex had significant effect on the clival width while the length was only significantly influenced by age but not sex. In the current study, neither sex nor age had significant effect on the clival index revealing that the proportions of the clivus in adults are stable across age and sex. This therefore limits the utility of clivus index in forensic identification of adult skulls. Age had a weak positive correlation with clival variables although these were not statistically significant. A strong positive correlation between age and clival dimensions was reported by Chaurasia *et al.* [28] and Aliyu *et al*., [5] possibly due to the inclusion of pediatric and adolescent participants who are still experiencing continued growth and development of the skull base. Our findings imply that the clival dimensions are not accurate skeletal markers for age estimation among adults.

The length of the clivus had a significant strong positive correlation with the clival width and this was consistent with the findings by Shalini *et al.* [21]. This suggests proportional development of the cranial base skeletal structures and coordinated growth of the clivus leading to its interdependent morphometric variables. Among Nigerians evaluated by Aliyu *et al*., [5] these two variables had a moderately positive correlation with each other. The study used a limited sample size due to its retrospective nature and the use of a single radiological center hence the data may not fully represent the wider population. The convenience sampling technique may possibly have introduced some bias during sample selection, further limiting the ability to generalize the findings to all Southern Nigerians. The study recommends future longitudinal studies using three-dimensional imaging models to elucidate the relationship between the clivus morphometry and age. Additionally, the association between clival variables and posterior cranial fossa and CVJ disorders and their surgical challenges can also be evaluated. Using a larger sample size from different radiological units in Nigeria, the accuracy of using clival measurements for sex determination can be assessed.

5. Conclusion

The present study demonstrated significant sexual dimorphism in clival length and width, suggesting that these parameters may serve as useful adjunct skeletal markers for sex estimation. In contrast, age had a negligible influence on clival dimensions, indicating their limited utility for age estimation in the adult population of Delta State, Nigeria. The population-specific morpho metric data generated in this study may assist in the preoperative planning of CVJ procedures and contribute to the future development of appropriately sized clival implants and fixation devices for the Nigerian population.

Declarations

Consent for publication: All authors approved the publication of this manuscript.

Data availability statement: The data set used in this study is available upon reasonable request from the corresponding author.

Competing Interests: None

Authors' Contributions: BSO conceptualized and designed the study, contributed to the definition of intellectual content, conducted the literature search, participated in the clinical studies, carried out data acquisition and data analysis, and contributed to manuscript preparation and editing. ODO contributed to the definition of intellectual content, conducted the literature search, participated in the clinical studies, and contributed to data analysis and statistical analysis, as well as manuscript preparation and review. SIS contributed to the study design, participated in the clinical studies, and contributed to data analysis and manuscript preparation. OJ conceptualized and designed the study, contributed to the definition of intellectual content, conducted the literature search, participated in the clinical studies, carried out data acquisition and data analysis, contributed to manuscript preparation, editing, and review, and served as guarantor of the study. MTE contributed to the definition of intellectual content, conducted the literature search, carried out data acquisition, contributed to statistical analysis, and participated in manuscript preparation. PSI contributed to the study concept and participated in manuscript editing and review. All authors approved the final version of the manuscript.

Funding: No funding was received for this study.

Acknowledgements: The authors extend their heartfelt gratitude to the radiological staff at Pharez Hospital and Diagnostics for their unwavering support during the time of data collection.

References

1. Gupta PP, Dhok AM, Shaikh ST, Patil AS, Gupta D, Jagdhane NN. Computed Tomography Evaluation of Craniovertebral Junction in Asymptomatic Central Rural Indian Population. J Neurosci Rural Pract. 2020; 11(3): 442–447.
2. Abdolmaleki M, Ghafari R, Pourkhalili R. Analysis of morphological and anthropometric variations of clivus using cone beam computed tomography in adults. Caspian J Dent Res. 2021; 10(1): 19–26.
3. Hedayatian M, Azarbayejani S, Omrani A, Borujeni SE. Correlation of Clivus Length and Angle with Chronological Age, Gender, Sagittal Growth Pattern of the Jaws, and Skeletal Maturation Using Lateral Cephalometry. J Dent (Shiraz). 2024; 25(3):251–261.
4. Chaurasia A, Patil R, Katheriya G. Radiomorphometeric Evaluation of Clivus in Indian Paediatric Population Visiting a Tertiary Dental Hospital-A Cone Beam Computed Tomography Study. Journal of Clinical and Diagnostic Research. 2018; 12(2): 05–08.
5. Aliyu AS, Bello R, Gudaji A, Abubakar M, Gaya AA, Zeera AM, Fage RI, Ahmad AA, Maigari YK. Age and Gender Variations in Clival Measurements: A Cross-Sectional Study from Federal Teaching Hospital Katsina Using CTscan. Journal of Experimental and Clinical Anatomy. 2025; 22(2): 338–343.
6. Furtado S V, Reddy K, Hegde AS. Posterior Fossa Morphometry in Symptomatic Pediatric and Adult Chiari I Malformation. Journal of Clinical Neuroscience. 2009; 16(11): 1449–`1454.
7. Moawad AM, Abu-Taleb NS, Hassan FM, Mahrous MM, Khalifa FN. Cone-beam Computed Tomography of the Clivus in an Egyptian Population Sample: A Forensic Perspective. Journal of Forensic Science and Medicine. 2025; 11(3): 219–227.
8. Diniz JM, Botelho RV. The Role of Clivus Length and Cranial Base Flexion Angle in Basilar Invagination and Chiari Malformation Pathophysiology. Neurol Sci. 2020; 41(7): 1751–1757.
9. Allen PA, Loth F, Loth D, Al Samman MM, Labuda R, Herrera C, Bapuraj JR, Klinge PM. Correlation of Anterior CSF Space in the Cervical Spine with Chicago Chiari Outcome Scale Score in Adult Females. J Neurosurg Spine. 2024; 42(3): 299–308.
10. Makhlouf F, Karwad M, Algezeri S. Morphological Measurements and Anatomical Variations of the Clivus Bone Using Computed Tomography in Adults, Benghazi. AlQalamJournal of Medical and Applied Sciences. 2025; 8(1): 471–475.
11. Ojha S, Debnath M, Ojha S, Debnath M. Sexual Dimorphism in Clivus Morphometry: A Multi-Detector Computed Tomography Study. Journal of Health and Allied Sciences NU. 2025; 15(3): 291–295.
12. Ji W, Tong J, Huang Z, Zheng M, Wu X, Chen J, Zhu, Q. A Clivus Plate Fixation for Reconstruction of Ventral Defect of the Craniovertebral Junction: A Novel Fixation Device for Craniovertebral Instability. Eur Spine J. 2015; 24(8): 1658–1665.
13. Aljuboori Z, Alhourani A, Nuru M, Nguyen C, Yeo H, Williams B, Andaluz N. Morphometric Study of the Posterior Fossa: Identification of Practical Parameters for Tailored Selection of Surgical Routes to the Petroclival Region. J Neurol Surg B Skull Base. 2022; 83(1): 37–43.
14. Batista UC, Joaquim AF, Fernandes YB, Mathias RN, Ghizoni E, Tedeschi H. Computed Tomography Evaluation of the Normal Craniocervical Junction Craniometry in 100 Asymptomatic Patients. Neurosurg Focus. 2015; 38(4): 1–6.
15. Kayacı S, Ozveren MF, Bas O, Ayberk G, Aslan MN, Sam B, Arslan YK. Effect of Clival Bone Growth on the Localization of the Abducens Nerve at the Petroclival Region: A Postmortem Anatomical Study. Surgical and Radiologic Anatomy. 2021; 43(6): 953–959.
16. Kumaran T, Yuvaraj BK. Morphometric Analysis of Intracranial Clivus in South Indian Skulls. J Res Med Dent Sci. 2020; 8(7):147–149.
17. Pandey S, Singh S, Gupta N, Nagar A, Arti A, Arya S, Sachan R. Extracranial clivus morphometry in Indian skulls: A Study for Optimizing Surgical Safety. Journal of Medical and Allied Sciences. 2025; 15(1): 47–47.
18. Nwotchouang BST, Eppelheimer MS, Bishop P, Biswas D, Andronowski JM, Bapuraj JR, Frim D, Labuda R, Amini R, Loth F. Three-Dimensional CT Morphometric Image Analysis of the Clivus and Sphenoid Sinus in Chiari Malformation Type I. Ann Biomed Eng. 2019; 47(11): 2284–2295.
19. Serindere G, Gunduz K, Avsever H. Morphological Measurement and Anatomical Variations of the Clivus Using Computed Tomography. J Neurol Surg B Skull Base. 2021; 83(Suppl 2): 75–82.
20. Shuman WH, DiRisio A, Carrasquilla A, Lamb CD, Quinones A, Pionteck A, Yang Y, Kurt M, Shrivastava RK.. Is there a Morphometric Cause of Chiari Malformation Type I? Analysis of existing literature. Neurosurg Rev. 2022; 45(1): 263–273.
21. ShaliniK, Katne T, Gotoor S, Gantala R, Kanaparthi A, Parthasarathy N. RadiomorphometricAnalysis of the clivus – A Soothsayer of Age and Gender. Journal of Oral and Maxillofacial Radiology. 2022; 10(3): 69–75.
22. Belgin CA, Bayrak S, Orhan K, Ankarali H. Multiple Regression Modeling for Age Estimation by Assessment and Comparison of Spheno-Occipital Synchondrosis Fusion and Cervical Vertebra Maturation Stages. J Neurol Surg B Skull Base. 2021; 83(3): 285–290.

23. Yilmaz N, Secgin Y, Atay I, Keskin N. Gender Estimation using Machine Learning Algorithms from Computed Tomography Images of Clivus. Medicine Science International Medical Journal. 2024; 13(3): 541.
24. Ominde BS, Enaohwo MT, Ogholo OD, Ikubor JE, Onogbe PO, Jeremiah O. Evaluation of the Evan's Index on Normal Brain Computed Tomography Scans of Adults in Delta State Nigeria. Niger Postgrad Med J. 2025; 32(1):47–52.
25. Ominde BS, Igbigbi PS. Morphometry of the Occipital Condyles in Adult Nigerians. Online Journal of Health and Allied Sciences. 2022; 20(4): 10.
26. Ominde BS, 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. 2022; 8(2): 46–51.
27. Ominde BS, Igabari JN, Ikubor JE. Morphometric Study of the Mastoid Process and its Role in Sex Differentiation: A Nigerian Computed Tomography Study. Journal of Forensic Science and Medicine. 2024; 10(1): 1–10.
28. Chaurasia A, Katheriya G, Patil R, Professor A. Radio-morphometric Evaluation of Clivus in Indian Ethnicity- A cone beam computed tomography study. Journal of Oral Medicine, Oral Surgery, Oral Pathology and Oral Radiology. 2017; 3(1): 35–41.