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Sexual Dimorphism in Clivus Morphometry: A Multi-Detector Computed Tomography Study

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ABSTRACT

Objectives: One of the most challenging tasks in forensic science is identifying a person from the fragments of an incomplete skeleton. Different landmarks in the human skeleton have been established to create the profile of an individual and only a few morphometric studies have been conducted to assess the clivus bone. This study utilized reconstructed computed tomographic (CT) images of the cranium to assess the dimension of the clivus bone and estimate its significance for sexual dimorphism.

Material and Methods: A total of 125 patients were included in the study and the dimension of the clivus bone was assessed using the Digital Imaging and Communications in Medicine (DICOM)Viewer.

Results: In the Gujarat population, the average clivus bone measured 4.09±0.577 cm in length and 2.69±0.617 cm in width. A significant difference in the clivus length was found, with a p-value <0.001. The overall cut-off value for sex prediction was 0.211, with a classification accuracy of 90.3% for males and 96.8% for females.

Conclusion: This study concludes that reconstructed CT images can be used for accurate anatomical morphometry and the length of the clivus bone can be used to identify the sex of an individual when other methods are indecisive.

Keywords: Clivus, Computed tomography, Forensic science, Morphometric analysis, Sex determination

INTRODUCTION

Identifying individuals from the remains of a skeleton is one of the most arduous tasks in forensic science and anthropology, as the retrieved skeletal remains are mostly incomplete. The remains of the skull can be promising for the generation of the profile of the individual.[1] The first step in identifying an incomplete skull is to confirm the sex. Multiple landmarks within the skull can be used for the identification of the sex, which includes the mandible, foramen magnum, orbits, maxillary sinus, etc.[2–5]

The clivus bone is one of the dense portions of the skull in the central part of the cranium base, extending from the dorsum sellae to the foramen magnum. It appears like a sloping surface in front of the foramen magnum and when viewed in the mid-sagittal section, it appears like a wedge-shaped structure. It is formed by the fusion of the posterior portion of the sphenoid bone, including the dorsum sellae, with the basilar part of the occipital bone.[6,7] The clivus is associated with important structures such as sella turcica, brain stem, abducens nerve, vertebral venous plexus, and other vascular structures running through its surface.[7,8] Rarely, the skull base is associated with clival chondroma 0.15–1% of all intracranial tumors. The increase in the size of the mass causes various neurological conditions.[9] Invasion of clivus by metastatic lesions can cause abducent nerve palsy.[10] To advance the surgical techniques and facilitate the safe surgical approach to clivus, a detailed morphometric analysis of the skull base must be done and evaluated.[11]

The clivus, being the most condensed part of the cranium, remains intact even after the injury to the cranium. The clivus can be the most promising landmark for the identification of an incomplete skull as it is not prone to physical damage due to its location in the skull base and strong physical build-up.

The study is conducted to facilitate forensic science by utilizing a morphometric analysis of the clivus using a radiological approach, which, in turn, will provide a dataset for skull

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base surgery planning in the Gujarat population and assess the significance of the clivus for sex determination using the Computed Tomography (CT) scan.

MATERIAL AND METHODS

A retrospective study was conducted among 125 patients who had undergone a routine CT scan of the cranium in a Secondary care hospital in Gujarat, India. The study included participants who underwent routine non-contrast CT brain scans and had no cranial deformities. Patients with a history of maxillofacial trauma or skull base surgery, as well as those younger than 18 years old due to incomplete ossification of spheno-occipital synchondrosis,[12] were excluded from the study.

The scan was carried out on Siemens Somatom scope 32-slice multi-detector CT using the routine brain protocol. The lateral scannogram was obtained with the patient in the supine position. The scan range was set from the top of the C1 lamina to the top of the calvarium. The scan was carried out in helical mode and data was acquired in the axial plane of slice thickness 5 mm and 5 mm incrementation. The scanning protocols were: (512 × 512 matrix, Field of View (FOV) 250 mm, 120 kVp, 250 mA).

The acquired CT images were extracted from the PACS (picture archiving and communication system) and further reconstructed into sagittal and axial images (1 mm thickness and 1 mm incrementation) in a sharp filter, i.e., bone window, using the multiplanar reconstruction (MPR) technique. Based on the previous studies, the intracranial length and width of the clivus were measured by using a digital caliper tool in the DICOM (Digital Imaging and Communications in Medicine) viewer.[13] The measurements include:

1. The length was measured as the points joining the superior part of the dorsum sellae to the edge of the foramen magnum in the sagittal image. The clival measurements were recorded as length and width in centimeters along with the demographic data such as age and sex [Figure 1(a)].
2. The width of the clivus was taken as the maximum distance measured by the calibration tool between the edges of the posterior portion of the sphenoid bone in the axial image [Figure 1(b)].

Statistical analysis

The data were analysed using IBM SPSS Statistics for Windows, version 26 (IBM Corp., Armonk, N.Y., USA) under different variables such as sex, length, and width. The inter-observer agreement was assessed using Cohen's kappa statistics between two observers and found almost in perfect agreement (k=0.82). The length and width of the clivus bone were assessed using mean and standard deviation. The normality of the variable was checked using the Kolmogorov-Smirnov test. The data distribution was found not normal, so the male and female clivus bone measurements were compared using the Mann-Whitney U test to determine whether there were any discernible differences. Binary logistic regression was employed to determine sex from the clivus bone measures. The receiver operator curve (ROC) was used to determine the cut-off value with the maximum sensitivity and specificity for sex differentiation. Charts and tables were used to display the data as percentages and frequencies.

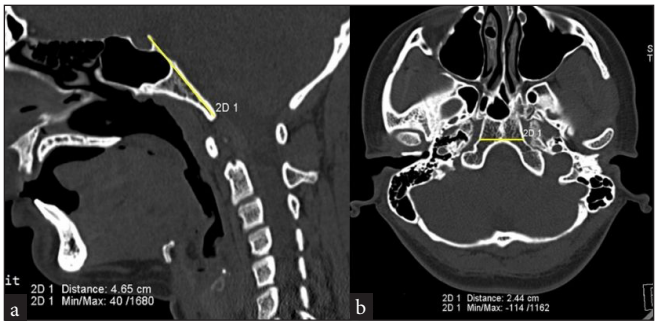

Figure 1: (a) Sagittal and (b) axial images of CT head in the bone window showing the landmarks for measurement of length and width of the clivus.

RESULTS

The study included 125 participants; 62 were male with a mean age of 37.48 ± 15.84 years, and 63 were female with a mean age of 43.71 ± 16.38 years. The descriptive statistics for the length and the width were reported [Table 1]. The mean length and width of the clivus bone in the Gujarat population were 4.09±0.577 cm and 2.69±0.617 cm, respectively. The mean dimension of the clivus bone was higher for the male group.

Mann-Whitney U test was utilized to evaluate the difference between the length and width of the clivus bone between the male and female groups. The test revealed significant differences in the length of the clivus bone of males (Median=4.35) and females (Median=4.01), U= 1008.5, z=4.665, p=0.00, and r=0.41 (Medium effect), where r is the effect size [Table 2].

Table 1: Table shows the mean length and width of clivus bone

Variables	Sex	Mean	Standard deviation (SD)	Minimum	Maximum
Length (cm)	Male	4.26	.523	2.40	4.94
	Female	3.92	.581	2.14	5.25
Width (cm)	Male	2.71	.567	1.95	4.47
	Female	2.67	.667	1.86	4.68

Table 2: Comparison of the variables among the groups							
Variables	**Male**			**Female**			**U-static (p-value)**
	Median	**Q1**	**Q3**	**Median**	**Q1**	**Q3**	
Length (cm)	4.35	4.13	4.60	4.01	3.75	4.27	(1008.5) **0.00***
Width (cm)	2.54	2.37	2.98	2.49	2.23	2.78	(1745) .304
Q1 and Q3: Interquartile range, *: Statistical significance							

We used binary logistic regression to investigate the relationship between clivus bone length and width as predictor variables and individual sex as the binary outcome in this study. The Nagelkerke R Square was used to measure the goodness of fit for the logistic regression model however, these test values indicated (0.213) closer to zero which means the model has a small proportion of variation in the dependent variable. This test is often relatively low in logistic regression because predicting the outcomes of binary models can be challenging. Therefore, we utilized the Hosmer and Lenesnow test to assess the goodness of fit of predictive probabilities. A non-significant Hosmer and Lenesnow test is considered a good fit for the model. The higher p-value in the Hosmer and Lenesnow test suggests that there is no significant difference, indicating a good fit for the model. In the present study, the value of Chi-square statistics is 3.046, and the p-value of 0.931 which indicates a better fit for the predictive model. This indicates that clivus bone length and width may be robust predictors of an individual's sex in our dataset.

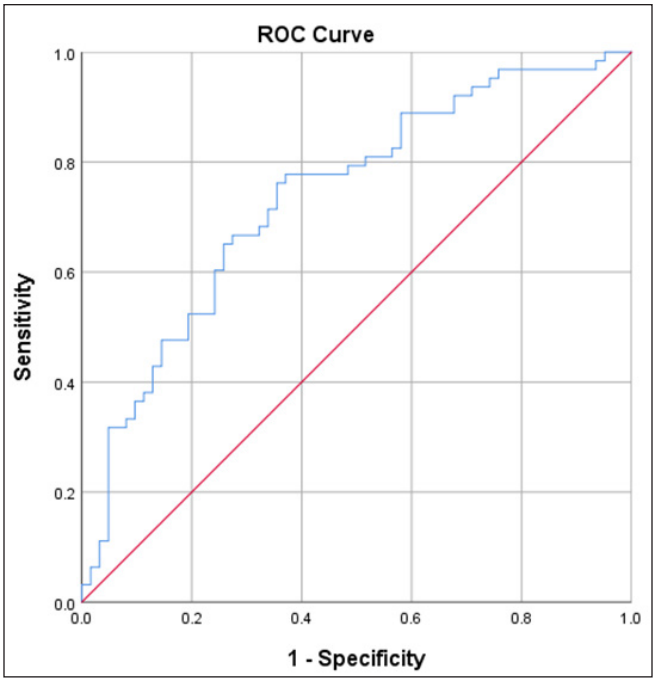

Figure 2: ROC curve shows the predictive probabilities (Red line represents the reference line, blue line represents the predicted probability). ROC: Receiver operator curve.

The ROC curve was utilized to assess the accuracy of identifying the sex of the individuals using the clivus length and width. An area under the curve in the present model is 0.737 (95% CI, 0.824 – 0.650), indicating the model is a good fit [Figure 2].

The overall optimum cut-off value for predicted probability is 0.211 having a 90.3% accurate classification for males and 96.8% for females [Table 3]. Based on the ROC curve, if the predictive probability is less than 0.211, it can be classified as male, and if more than or equal to 0.211, female.

Table 3: Prediction accuracy for sexual dimorphism of clivus bone			
		Male	**Female**
Prediction based on a cut-off of 0.211	**Male**	56	2
		90.3%	3.2%
	Female	6	61
		9.7%	96.8%
Total		62	63

DISCUSSION

The clivus is one of the important landmarks in the cranium, closely associated with the central nervous system and other important vascular structures within the skull.[7] In the event of forensic investigations, the clivus may provide crucial information about the individual because it is relatively dense and located in the base of the skull, decreasing the probability of it being destroyed. This study aimed to measure and compare the dimension of the clivus between male and female groups using the CT images.

In the present study, the morphometric analysis of clivus bone revealed that the clivus dimension was found to be slightly higher in males than in females. The mean length of clivus was 4.26±.523, 3.92±.581 cm, and the mean width was 2.71±.567, 2.67±.667 cm for males and females, respectively. A significant difference was noted in the length of the clivus between males and females ($p < 0.001$).

Accordingly, a similar study conducted by Chaurasia et al., 2018 in the Indian population reported that, in line with the current findings, the mean length and width of the clivus were greater in males than in females, and a significant difference was noted only in the length of the clivus. The mean length of clivus was 43.99±3.82 and 41.39±3.73 mm, and the mean width was 29.22±4.28 and 28.52±3.29 mm for males and females, respectively.[13] In addition, Jehan et al., 2014 reported similar findings in which the mean length and width of the clivus were greater in males than in females. The mean length of clivus reported was 4.59±0.30 and 4.39±0.24 cm, and the width was 2.98±0.98 and 2.64±0.23 cm for males and females, respectively. It was observed that there were significant differences in both the clivus's length and width between males and females.[6] Moreover, the study conducted by Shalini et al., 2022 reported similar findings and emphasized the use of the clivus dimension for the identification of individuals when other parameters are non-conclusive in medicolegal cases. The mean length of clivus reported was 43.03±1.19 and 42.15±0.71 mm, and the mean width reported was 29.74±1.57 and 28.52±1.11 mm for males and females, respectively.[14]

A study conducted by Serindere *et al*., 2021 used clivus for sexual dimorphism in the Turkish population and reported a positive correlation between the length of clivus and gender. The mean length of the clivus was 46.19±4.12 mm and 44.22±3.94 mm for males and females, respectively, which was slightly higher than the readings from the studies conducted in the Indian population.[15] A study conducted on the Iranian population by Abdolmaleki et al., 2021 reported a significant difference in the length of clivus between males and females, where the mean length of clivus was 45.72±3.56, 41.56±2.88 mm and width 31.32±2.61, 31.49±2.14 mm for males and females population respectively.[16]

The mean dimension of clivus across the Indian population was found to be nearly comparable, suggesting relatively homogenous morphology among the Indian population. However, a small difference in the clivus's morphometry was observed compared to studies from other populations. Different genetic makeup, ethnic differences, and regional anatomical variations could all contribute to this distinction.

In the current study, the overall cut-off value was calculated as 0.211; if the value is less than 0.211, it can be identified as male, and if it is more than or equal to the given value, it is identified as female with an accuracy of 90.3% for male and 96.8% for female suggesting good fit for forensic analysis. In the study conducted by Jehan et al., 2014 using the analysis of variance, the overall accuracy of correct identification of sex was reported at 76.43% for males and 77.94% for females.[6] The variation in the accuracy might be because of the different measurement techniques utilized in the study.

Limitation

The major limitations of the study are the limited sample size and the use of only two variables of the clivus for the morphometry; multiple potential variables could be taken into consideration. As there are limited studies conducted in this region, so further studies with larger sample sizes and using multiple variables can be done.

CONCLUSION

In conclusion, this study's findings indicate that the length of the clivus bone in the adult Gujarat population displays sexual dimorphism. When other landmarks within the cranium yield inadequate results, the clivus can be a promising landmark for identifying an individual because of its strong physical build-up and its location in the skull base. The morphometric measurements obtained from reconstructed Computed Tomography images can be crucial and advantageous for forensic medicine and anthropometric analysis.

Ethical approval: The research/study approved by the Institutional Ethical Committee at Charotar University of Science and Technology, number CHA/IEC/ADM/23/01/036.02, dated 11th January 2023.
Declaration of patient consent: Patient's consent not required as patients identity is not disclosed or compromised.
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