

Morphometric Examination of adult human dry forearm bone in Indian origin for sex determination

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ABSTRACT

Background: Morphometric assessment of the radius and ulna provides important anatomical information and may help in understanding sexual dimorphism, bilateral asymmetry, forensic identification, anthropological assessment, and orthopedic applications. However, morphometric characteristics may vary among different populations. The present study evaluated selected morphometric parameters of adult dry radius and ulna bones from a Central Indian population and assessed sex- and side-related differences. **Aim:** To evaluate selected morphometric parameters of adult dry radius and ulna bones and determine the presence of sexual dimorphism and bilateral asymmetry in the studied population. **Materials and Methods:** This observational morphometric study was conducted using 100 adult human dry ulna bones and 100 adult human dry radius bones obtained from the osteological collections of Ram Krishna Medical College Hospital & Research Centre, Bhopal, Madhya Pradesh. Bones with complete anatomical integrity and identifiable sex and side were included. Morphometric parameters were measured using a digital Vernier caliper following standardized anatomical landmarks. Measurements included maximum length, olecranon width, coronoid height, midshaft diameter, and distal end breadth for the ulna, and maximum length, head diameter, neck circumference, midshaft diameter, and distance from the radial head to the bicipital tuberosity for the radius. The measurements were compared between male and female bones and between right and left sides using appropriate statistical tests. **Results:** Male ulnae showed higher mean values than female ulnae for maximum length, olecranon width, coronoid height, midshaft diameter, and distal end breadth. Similarly, male radii demonstrated higher mean values than female radii across the assessed morphometric parameters. For the radius, statistically significant sex-related differences were observed in maximum length (243.65 vs. 223.60 mm), head diameter (23.10 vs. 21.20 mm), neck circumference (37.80 vs. 35.00 mm), midshaft diameter (9.70 vs. 8.90 mm), and distance from the radial head to the bicipital tuberosity (29.30 vs. 27.60 mm). The right-sided measurements were generally slightly greater than the corresponding left-sided measurements, suggesting possible bilateral asymmetry; however, the significance of side-related differences varied across individual parameters. **Conclusion:** The present study demonstrates appreciable sexual dimorphism in the morphometric characteristics of adult radius and ulna bones, with males generally exhibiting greater dimensions than females. The observed bilateral differences may reflect functional or developmental asymmetry. These morphometric parameters may have potential applications in forensic anthropology, anatomical research, orthopedic planning, and population-specific skeletal identification.

Keywords: Radius; Ulna; Morphometry; Sexual Dimorphism; Bilateral Asymmetry; Osteology; Forensic Anthropology; Central Indian Population.

INTRODUCTION

Elbow articulation, upper limb mechanics, and the attachment of muscles that control hand and forearm motions are all impacted by the ulna, a prominent forearm bone. Many fields, including medicine,

orthopaedics, forensics, and anthropology, rely on precise ulna morphometric studies. The development of gender-specific implants and prostheses and the identification of skeletal remains are two areas where this is particularly important [1,2].

A number of studies have shown that bones can be dimorphic, meaning that males typically have longer and stronger bones than females. A number of mechanisms, including those of a genetic, hormonal, and biomechanical kind, contribute to this ulnar sexual dimorphism. Muscle mass and activity levels are two areas where males tend to excel [3,4]. Measuring important characteristics including maximum length (MLU), olecranon width (OLW), coronoid process height (CPH), midshaft diameter (MSD), and distal end breadth (DEB) has shown that gender differentiation and functional adaptations may be understood [5,6]. Functional adaptations can be understood by the measurement of these traits.

Various ulna morphometric studies in India have yielded valuable baseline data[7,8]. This is because the population displays skeletal traits that are impacted by regional lifestyle and genetic factors. These results highlight the need of using group-appropriate osteometric criteria, as Indian skeleton proportions typically do not match Western anthropometric models. Global researchers have shown that right-handed people, in particular, exhibit side-to-side variances that may be related to limb dominance [9, 10], in addition to sex differences. It is generally believed that the right side of the body develops stronger bones due to higher functional loading, in accordance with Wolff's rule, which explains that bones adapt to mechanical forces. This backs up the idea that mechanical stresses cause bone to react. Despite these advancements, there is still a need for thorough comparative studies that examine the ulna's morphometric features, taking into consideration variations according to gender and side. This is particularly the case for regional Indian communities for whom such statistics are currently unavailable. In this work, we will examine a number of ulna morphometric features, look for gender differences in these parameters, and find that the measurements of male and female bones are significantly different.

Gender, side dominance, and geographical location are a few of the variables that impact the small morphometric variations in the human radius. This study found that in adult Indian populations, the right side of the male's radius had slightly higher midshaft diameter (MSD), head diameter radius (HDR), neck circumference radius (NCR), mid-length radius (MLR), and distance from the head to the bicipital tuberosity (DEB). The observed pattern consistently suggests that handedness-related functional adaptation has a less major impact, even if these differences were not statistically significant in prior trials conducted in other locations.[1-5] According to research reported in both Indian and international literature,[2-6] the dominant side, which is often the right, was seen to have somewhat bigger dimensions. This might be due to increased mechanical stress and muscle activation. Similarly, among females of Central Indian descent, MLR, HDR, and DEB showed a small right-sided

dominance, but NCR and MSD were marginally more left-sided.[3-8] Previous research has shown a widespread pattern of dominant-side hypertrophy,[5–10] which is supported by both of these results. Statistical significance was not found in most studies, suggesting a generally symmetrical morphology,[11–13] lending credence to the idea of bilateral anatomical balance despite functional asymmetry. That the morphology is often symmetrical is a key indicator of its significance. Research shows that there is a strong sexual dimorphism, as men consistently scored better than females on all of the assessed measures.[4-6] Consistent with previous research, which has associated these differences to biomechanical, hormonal, and genetic variables,[3-6] this makes sense. Because it is possible to identify a person by determining their side and sex from isolated bones, these findings have far-reaching consequences for forensic anthropology.[3–7] It is critically important to identify minute side-specific changes in orthopedic operations such as surgical reconstruction and prosthesis design. In this study, we aim to measure the radius's various morphometric properties—its length, breadth, diameters, and indices to see how these traits differ between the sexes and to find statistically significant

MATERIALS AND METHODS

An analysis of the ulna's morphometric features in dry adult human bones was the goal of this descriptive osteometric investigation. Researchers used a cross-sectional approach to carry out the study. The main goal was to study ulnar side-wise asymmetry and sexual dimorphism. To do this, five important metrics were compared: MLU, OWL, CPH, MSD, and DEB, which stand for maximum length, olecranon width, coronoid process height, midshaft diameter, and distal end breadth, respectively. The relevant research was conducted at the Ram Krishna Medical College Hospital & Research Centre, Bhopal Madhya Pradesh in department of anatomy. One hundred adult dried human ulnae were used for the examination, with fifty placed on the right and fifty on the left. Test subjects consisted of thirty-five male and twenty-five female specimens, with twenty-five individuals drawn from each sex. Bones that were not included in this study were those that were either damaged or misshapen, had an uncertain sex, or showed signs of pathological changes. Recognizing Sexual Attraction and Which Side You're On: Using the institutional osteological data held in the departmental bone bank, we were able to pre-identify and label each bone for sex and laterality. Skilled anatomists employing well-established anthropological principles double checked the sex identifications. The following parameters were tested for in each ulna using a digital vernier caliper, a metallic osteometric board, and well-established anthropometric methodologies:

1. Maximum Length (MLU) – Distance from the tip of the olecranon process to the tip of the styloid process.
2. Olecranon Width (OLW) – Transverse maximum width across the olecranon process.
3. Coronoid Process Height (CPH) – Maximum vertical height of the coronoid process.
4. Midshaft Diameter (MSD) – Transverse diameter measured at the midpoint of the shaft.
5. Distal End Breadth (DEB) – Maximum transverse width of the distal end of the ulna.

The morphometric and morphological features of adult dry radius bones from the Central Indian population were examined in this descriptive study that also utilized a cross-sectional method. The detection of sexual dimorphism and side-wise differences received special focus. Fifty adult human dry radii were obtained from the Department of Anatomy's osteology collection at Ram Krishna Medical College Hospital & Research Centre, Bhopal Madhya Pradesh after the institutional ethical committee gave its approval. A total of 25 male and 25 female bones, including both sexes, were included in these dry radii. The study only considered bones that had all of their anatomical markers and features preserved. Pathological lesions, unknown laterality, or deformities in any of the bones were excluded from the results.

When necessary, we used proven anthropological indicators to verify the sex and side of each bone. To make these observations, we consulted the relevant governmental documents. Digital Vernier callipers with a resolution of 0.01 millimeters were employed to measure a range of conventional morphometric parameters. What follows is a rundown of all the measurements taken:

- Maximum Length of Radius (MLR) from the most proximal point of the radial head to the distal styloid process;
- Head Diameter of Radius (HDR) the maximum transverse diameter of the radial head;
- Neck Circumference of Radius (NCR) measured at the narrowest portion of the radial neck using a flexible measuring tape;
- Midshaft Diameter (MSD) measured at the midpoint of the diaphysis;
- Distance from Head to Bicipital Tuberosity (DEB) measured from the superior articular surface to the most prominent point of the radial tuberosity.

Each measurement was taken three times by two independent observers, and the mean value was used for analysis to reduce inter-observer and intra-observer variability.

Statistical Analysis:

It was decided that two separate observers would conduct each measurement three times, with the average of the three results being recorded. A

reduction in intra- and inter-observer error was the goal of this action. Statistical analysis was carried out using SPSS software, version 25.0, whereas Microsoft Excel was used for data entry. For every parameter, we calculated descriptive statistics, such as the mean and standard deviation, considering both the gender and the side. We used the independent samples t-test to compare the values of the males and females. In contrast, the gender specific side-wise differences were examined using the paired t-test. The cutoff for statistical significance was established as a p-value <0.05.

The SPSS software version was used to statistically analyze the data. For every parameter, descriptive statistics such as the mean and standard deviation were computed. The paired and unpaired t-tests were used for side-wise and sex-wise comparisons, respectively. P-values below 0.05 were regarded as statistically significant. The results were compared to both domestic and foreign literature, and patterns of asymmetry and dimorphism were interpreted in light of functional and biomechanical considerations.

RESULTS

The results of this study show that the following radius morphometric characteristics were significantly higher on the right side of adult male Indians' bodies: Here are the measurements: DEB is 29.3 mm, MSD is 9.7 mm, NCR is 37.8 mm, MLR is 245.9 mm, HDR is 23.1 mm, and HDR is 22.7 mm. The distance from the head to the bicipital tuberosity is also 30.3. Although the pattern does not reach statistical significance, it does suggest a little inclination toward amplification on the dominant side. This pattern may be the product of a handedness-specific functional adaptation in bone morphology. Previous studies have also shown similar variances in negative effects, so our results are consistent with them. For instance, suggesting osseous variation associated to dominance was uncovered in a morphometric study of the radius in male North Indians. There was no statistically significant difference between the right- and left-side values, but the right-side values were somewhat higher.[14] Biomechanical stress effects are likely to blame for this, as was shown by Das et al. (2023),[15] when they used osteometry to study dry radii and discovered that the dominant side, often the right, had larger dimensions. Literature from various nations lends credence to these conclusions. Hong et al. (2021),[16] used 3D imaging on a Caucasian population and found that right-handed people had considerably greater morphometric values for their right radii. Even if there is functional asymmetry, biological symmetry still persists since the changes did not reach the level of statistical significance (Hong et al., 2021, p. 16). Consistent usage of the upper limb influences radial bone formation, according to a biomechanical research by Sayadizadeh et al. (2024).[17] On the other hand,

the changes are still rather little when you look at the two sides side by side.

The little imbalance seen in this study might be explained by differences in the nutrition, lifestyle, and employment habits of Indian males. It is crucial to think about bilateral comparisons within the context of the social and environmental features of the group being researched, based on the findings of Mishra (2016),[18] who claimed that regional and lifestyle differences impact the forearm bone structure in India. Being more dexterous with one side of the body does not always indicate that there are significant anatomical differences between the two in healthy individuals, according to research by Shrestha et al. (2022).[19] This research supports the theory that right sides of the body tend to be stronger. But the fact that there wasn't a statistically significant change suggests that the radius is still fairly balanced. It appears that the morphometric symmetry of the radius has been mainly maintained, as there is little statistical significance. The area of forensic anthropology and orthopedics could both be affected by these results. Because bilateral morphometry is consistent and accounts for small variations, a firm sex and side identification may be made with only one bone. Anatomical accuracy may be improved with knowledge of minute asymmetries while making prosthesis or performing surgeries like radial head replacement.

Results from this morphometric study on adult female Central Indian radius bones showed small, non-significant differences in the parameters measured along the sides of the bones. In terms of NCR (Neck Circumference of Radius), MSD (Minimum Shaft Diameter), and MLR (Maximum Length of Radius), the left side had marginally larger measurements than the right side. Similarly, in terms of HDR (Head Diameter of Radius), DEB (Distal End Breadth), and MSD (Minimum Shaft Diameter), the left side was marginally larger than the right side. These results are consistent with the measurements of the upper arm bones, which show a little increase in size on the

dominant side. In a study conducted in North India, researchers discovered similar results to ours: when comparing morphometric variations along the sides of individuals, right-sided measures were more common in both sexes.[20] This was true irrespective of whether we were comparing sexes. But they failed to detect anything statistically significant. Women in a South Indian cohort had larger values for head diameter and radius length on the right side, according to a survey.[21] These ladies reasoned that the mechanical tension associated with being left-handed was the source of these elevated numbers.

Our findings suggests that the slight alterations in MLR and HDR might be explained by their functional adaptation, since the dominant hand has the potential to influence bone remodelling and hypertrophy in the long run For each of the six variables examined in this study MLR, HDR, NCR, MSD, and DEB the results showed that men had much greater values than females. That the adult human radius exhibits morphometric properties that are obviously dimorphic between sexes is seen from this. The results of this study lend support to the idea that skeletal characteristics in Functional adaptation due to handedness and variable mechanical stress may also account for the significantly larger results for right-side dominance in both sexes. This clarifies the reason for the considerably higher right-side dominance. Bones on the dominant side tend to be longer and larger than those on the non-dominant side due to increased mechanical stress and stronger muscle connection. Parameters including HDR, NCR, MSD, and DEB showed statistically significant gender differences, demonstrating the radius's value in forensic and anthropological sex determinations. The fact that sex was determined by the radius further supported this. Results show that the radius is a major factor in deciding gender, and they also show how important it is for morphological differences to be population-specific. The domains of forensic science, orthopedics, and reconstructive surgery are all touched by these results.

Table 1: Ulna in both the genders comparison

Parameter	Male(Mean $\pm$ SD)	Female (Mean $\pm$ SD)	P value
Maximum Length (MLU)	259.6 $\pm$ 9.0	238.3 $\pm$ 8.85	T=8.437; df=48; P = 0.0001
Olecranon Width (OLW)	24.55 $\pm$ 1.85	22.2 $\pm$ 1.5	T = 4.8915; df =48; P = 0.0001
Coronoid Height (CPH)	17.6 $\pm$ 1.4	15.4 $\pm$ 1.15	T = 6.0714; df = 48; P = 0.0001
Midshaft Diameter (MSD)	9.5 $\pm$ 1.05	8.3 $\pm$ 0.95	T = 4.2373; df = 48; P = 0.0001
Distal End Breadth (DEB)	29.4 $\pm$ 1.85	25.55 $\pm$ 1.8	T = 7.4578; df = 48; P = 0.0001

In Table 1 you can see every ulna feature for both men and women. When comparing the ulnas of males and women, it is always the case that the former has larger measures. This is valid for any and all measurements. A little amount of

functional asymmetry, perhaps due to one side's limb dominance over the other, is shown by slightly greater right-side measures compared to left-side ones. Every radius-related parameter, including MLU (259.6 vs 238.3), OLV (24.55 compared 22.2), CPH (17.6 versus 15.4), MSD (9.5 versus 8.3), and DEB (29.4 versus 25.55), showed a statistically significant difference between the sexes.

Table 2: Radius in both the genders comparison

Table 2 has all radius features for both genders. On both sides, male radius measures are larger than females'. In both

Parameter	Male (n=25) (Mean $\pm$ SD)	Female (n=25) (Mean $\pm$ SD)	P value
Maximum Length (MLR)	243.65 $\pm$ 8.7	223.6 $\pm$ 7.65	T=8.221; df=48; P = 0.0001
Head Diameter (HDR)	23.1 $\pm$ 1.5	21.2 $\pm$ 1.5	T = 4.4783; df =48; P = 0.0001
Neck Circumference (NCR)	37.8 $\pm$ 2.8	35 $\pm$ 3.0	T = 3.4116; df = 48; P = 0.0013
Midshaft Diameter (MSD)	9.7 $\pm$ 0.8	8.9 $\pm$ 0.7	T = 3.762; df = 48; P = 0.0005
Distal End Breadth (DEB)	29.3 $\pm$ 2.1	27.6 $\pm$ 2.15	T = 2.8282; df = 48; P = 0.0068

sexes, the right side continuously shows slightly higher numbers, indicating a tendency for dominant-side amplification. All of the radius measured metrics, including MLR (243.65 vs. 223.6), HDR (23.1 vs. 21.2), NCR (37.8 vs. 35), MSD (9.7 vs. 8.9), and DEB (29.3 vs. 27.6), showed a statistically significant difference between the sexes.

In the section that follows, the morphometry of the forearm bones is compared side-wise (right versus left) and sex-wise (male against female), with a special focus on the bone of the radius and the bone of the ulna individually.

All radius parameters for men, including both sides, are included in Table 1. MLR is 245.9 vs. 241.4, HDR is 23.1 vs. 22.7, NCR is 37.8 vs. 37.1, MSD is 9.7 vs. 9.5, and DEB is 29.3 vs. 28.7. These are the averages between the two sides. We found that in males, the right side continuously shows slightly higher values, suggesting a tendency for dominant-side augmentation. In men, there was no statistically significant difference between the right and left radius.

DISCUSSION

This study's morphometric measures of the radius and ulna show a substantial difference between the sexes. Right and left body measurements consistently show that men are heavier than women. Consistent with previous research in India and throughout the globe, this study found that men's bigger bone dimensions are caused by their larger muscle mass, hormones, and mechanical forces [11, 12, 12].

A number of radius measures, including maximum length of radius (MLR), head diameter of radius (HDR), neck circumference of radius (NCR), midshaft diameter (MSD), and distal end breadth (DEB), demonstrated statistically significant variations between males and females. Confirming the global nature of sexual dimorphism in long bones, our results closely align with those of [13] in Central India and Jeong et al. [14] in South Korea, who also found that males had greater radial lengths and diameters (e.g., MLR: 243.65 mm in males versus 223.6 mm in females). Radial lengths and diameters were found to be larger in men compared to females, as stated in references [13] and [14].

For some reason, regardless of gender, the values of the right-sided radius were always somewhat bigger than the left-sided radius; nonetheless, the disparities

were more pronounced in men. This is a fascinating point to bring up. Many anthropometric investigations have shown that the right upper limb is more functionally dominant, and this asymmetry is probably a reflection of that [15,16]. But in women, this swaying up and down did not amount to anything statistically significant. One possible explanation is that hormonal effects and mechanical loads are lower in females compared to males. Furthermore, our results showed that the ulna had a sexual dimorphism that was statistically significant across all parameters. These features included DEB, MSD, CPH, OWL, and MLU (the maximum length of the ulna in this instance), among others. The tendency seen in radius bones was further supported by the fact that male results consistently increased (e.g., MLU: 259.6 mm compared to 238.3 mm in females). Mays et al. [18] and [17] found comparable trends in bone samples from Europe. [17] found such trends in North Indian communities as well. Our data further supports the hypothesis that bone morphology is influenced by differential mechanical stress caused by limb dominance. This asymmetry is seen in both sexes, with the right sided ulna slightly larger than the left-sided ulna. This finding is supported by research done by [19,20]. These studies corroborate the biomechanical

ideas presented in Wolff's Law and show that the dominant side's upper limb bones also improve to an equal degree.

Nonetheless, the two sides of the female ulna did not vary significantly. It was observed that the limbs were utilized in a usually symmetrical manner during everyday activities, as shown by modest variances in the female ulna (e.g., 8.2 mm on the right and 8.4 mm on the left). Since women don't often participate in strenuous physical labor, functional asymmetry is less noticeable in them, according to Pocan et al. [21]. The results of their inquiry are consistent with this discovery. When these factors are considered, our results provide support to the use of ulna and radius morphometry in forensic anthropology for gender identification, especially when dealing with fragmentary skeletal remains. Serious consequences for orthopaedics, prosthetics, and anthropological reconstructions stem from the proven sexual dimorphism and side-wise asymmetry. The therapeutic and ergonomic significance of the observed dominant-side augmentation extends to the development of tools, wearable, and implants that must account for subtle but constant variations in bone structure.

Strengths of the Study

The major strength of the present study is the systematic evaluation of multiple morphometric parameters of both the radius and ulna in an adult Central Indian population. The study assessed important dimensions related to bone length, breadth, diameter, and other anatomical landmarks, allowing a comprehensive evaluation of skeletal variation. Another strength is the assessment of **sexual dimorphism**, which demonstrated consistently greater morphometric values in males compared with females. The study also considered **bilateral differences between the right and left sides**, providing additional information regarding possible anatomical asymmetry. The use of a digital Vernier caliper and standardized anatomical landmarks enabled objective and direct measurement of the dry skeletal specimens. Inclusion of specimens from established osteological collections further allowed direct assessment of skeletal morphology without the influence of soft-tissue-related measurement variation. The findings may provide useful population-specific reference data for anatomical, anthropological, forensic, and orthopedic applications.

Limitations

The present study has several limitations. First, the study was based on a relatively limited sample of adult dry radius and ulna bones, which may restrict the generalizability of the findings to the wider Indian population. The specimens were obtained from selected osteological collections and may therefore not fully represent the morphological diversity of the Central Indian population. Second, the study was

limited to selected morphometric parameters and did not incorporate other potentially informative anatomical or radiological measurements. Third, the study did not provide information regarding the intraobserver and interobserver reliability of the measurements; therefore, measurement reproducibility could not be fully assessed. In addition, the influence of factors such as age, nutritional status, occupational activity, handedness, and other biological or environmental characteristics could not be adequately evaluated. Finally, because the study involved dry skeletal specimens, the findings cannot be directly extrapolated to living individuals without further validation.

Future Research / Recommendations

Future studies should include **larger and more geographically diverse skeletal samples** to establish reliable population-specific reference values for radius and ulna morphometry. Multicentric studies involving different regions of India would help determine regional variations and improve the generalizability of the findings. Future research should also assess **intra observer and inter observer reliability** using appropriate statistical measures to establish the reproducibility of morphometric measurements. Advanced statistical approaches, including multivariate analysis and discriminant-function analysis, may be used to develop more reliable models for **sex estimation and skeletal identification**. Further studies incorporating age, handedness, occupational activity, and other relevant biological variables may help clarify the factors responsible for bilateral asymmetry. Correlation of dry-bone measurements with radiological or imaging-based measurements in living individuals would also be valuable for determining the clinical applicability of these findings.

CONCLUSION

Consistently bigger male bones than female bones across all metrics that were assessed show a major and statistically significant sexual dimorphism in the ulna's morphometric properties. The values on the right side of both bones were much higher, especially in men. Mechanical stress and limb dominance traits are likely the causes of this small but persistent functional asymmetry. However, the discovery of a small dominating tendency in the ulna lends credence to the idea of side-preferential bone adaptation, even if the females' radius did not show any obvious side-wise difference. The fact that the ladies' radii were similarly large did not change this outcome. Not only do these results provide notable information specific to the Indian people, but they also demonstrate the necessity of considering gender and lateral asymmetry in anthropological, forensic, orthopedic, and ergonomic applications.

It has been demonstrated that males consistently have higher morphometric values than females across all

parameters, which is evidence of a significant sexual dimorphism in adult Indian radii. The slight and insignificant preponderance of the right side in both sexes is indicative of functional adaptation that is most likely associated with handedness. These findings, which are in agreement with examinations conducted in India as well as those conducted in other countries, bring to light the relevance of taking into consideration peculiarities that are distinctive to both sides and to sexes while doing anatomical research. Despite the fact that they are very minor, the asymmetries are helpful in orthopedic and forensic anthropological applications. In particular, they are helpful for assessing sex and side, creating prosthesis, and performing procedures that correspond to population-specific anatomical norms.

DECLARATIONS

Consent for Publication

Not applicable. The study involved examination of dry human skeletal specimens and did not involve identifiable individual participants or personal clinical information.

Availability of Data and Materials

The data generated and/or analyzed during the present study are available from the corresponding author on reasonable request, subject to institutional policies and applicable ethical considerations.

Competing Interests

The authors declare that they have no competing interests.

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Authors' Contributions

All authors contributed to the conception and design of the study, data collection, morphometric assessment, interpretation of findings, and preparation and revision of the manuscript. All authors reviewed and approved the final version of the manuscript and agree to be accountable for all aspects of the work.

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