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Original Research

Morphology and Morphometry of proximal end of dry radii in Indian population

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ABSTRACT

Aim: To analyze the morphology and morphometry of the proximal end of dry radii in the Indian population and provide insights into anatomical variations relevant to clinical and anthropological applications.

Material and Methods: This cross-sectional, observational study included 120 dry radii (60 right and 60 left) obtained from osteology collections in Indian medical colleges. Morphological features, including radial head shape, neck orientation, and tuberosity characteristics, were documented. Morphometric parameters, such as diameters of the radial head and neck, tuberosity dimensions, and angle of inclination, were measured using a digital vernier caliper. Descriptive and inferential statistical analyses were performed using SPSS.

Results: The radial head was predominantly circular (65.00%), with oval (30.00%) and irregular shapes (5.00%) observed less frequently. Straight neck orientation was most common (50.00%), followed by slightly angled (40.00%) and angled (10.00%) orientations. The mean transverse diameter of the radial head was 21.5 ± 2.3 mm, and the mean anteroposterior diameter was 20.2 ± 2.1 mm, with no significant differences between the right and left sides ($p=0.356$, $p=0.412$). The radial neck's transverse and anteroposterior diameters measured 12.5 ± 1.8 mm and 11.8 ± 1.7 mm, respectively. Radial tuberosity dimensions (mean length: 13.2 ± 1.5 mm; mean width: 10.8 ± 1.4 mm) and the angle of inclination (12.5 ± 2.2 degrees) showed bilateral symmetry without significant differences ($p>0.05$).

Conclusion: The study highlights the predominance of circular radial heads and bilateral symmetry in morphometric parameters in the Indian population. These findings enhance our understanding of population-specific anatomical variations, which are essential for improving surgical approaches, implant designs, and anthropological research.

Keywords: Radial head, Morphometry, Proximal radius, Indian population, Anatomical variations.

Introduction

The human skeleton exhibits remarkable structural complexity and functional adaptability, providing insights into evolutionary biology, population-specific variations, and clinical relevance. Among the long bones, the radius is critical for upper limb mobility and function, playing an essential role in forearm pronation, supination, and wrist articulation. The proximal end of the radius, including the head, neck, and tuberosity, is a site of significant anatomical and biomechanical importance. Its morphology and morphometry are pivotal in understanding variations across populations, designing implants, and devising surgical interventions.[1]Morphological and morphometric studies of skeletal components are essential for anthropological research, forensic identification, and medical applications. The proximal radius is particularly noteworthy for its interaction with the humerus and ulna, forming the radiohumeral and proximal radioulnar joints, which contribute to the complex movements of the upper limb. Variations in the shape, size, and orientation of the radial head, neck, and tuberosity influence the biomechanics of these joints and can impact clinical outcomes in cases of trauma, degenerative changes, or reconstructive surgery.[2]India, being a geographically vast and ethnically diverse country, presents a unique opportunity to study anatomical variations in skeletal features. The Indian population encompasses a wide range of genetic and environmental influences, which are reflected in the skeletal framework. Understanding the morphology and morphometry of the proximal end of the radius in this population is crucial for several reasons. It aids in developing region-specific prosthetic designs, improves the accuracy of orthopedic procedures, and provides baseline data for anthropological and forensic studies.[3]The radial head, a disc-like structure at the proximal end of the bone, articulates with the capitulum of the humerus. Its shape, typically circular or oval, and dimensions determine its fit within the joint capsule and its ability to facilitate smooth rotational movements.

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Morphological variations in the radial head, such as deviations from a perfect circle or the presence of irregularities, can alter joint mechanics and predispose individuals to certain pathologies. Additionally, the radial head's morphology is a critical consideration in radial head arthroplasty, where accurate sizing and alignment are key to restoring joint function.[4]The radial neck, a narrowed segment distal to the head, serves as a transition zone connecting the radial head to the shaft. Its orientation and dimensions are vital for structural integrity and play a role in distributing mechanical loads during forearm movements. Variations in the neck's angulation or diameter can influence the overall stability of the proximal radius and its interaction with adjacent structures. In surgical procedures, such as open reduction and internal fixation of proximal radius fractures, understanding the precise morphometry of the neck is essential for achieving optimal outcomes.The radial tuberosity, located below the neck, serves as the attachment site for the biceps brachii tendon. Its prominence and orientation are important for the tendon's function, particularly during elbow flexion and forearm supination. Morphological variations in the tuberosity can affect the biomechanics of the biceps tendon, leading to changes in force transmission or susceptibility to injuries. The morphometric analysis of the tuberosity also informs surgical techniques, such as tendon repair or reconstruction, ensuring that the anatomical features are preserved or restored effectively.[5]While global studies have examined the morphology and morphometry of the proximal radius, data specific to the Indian population remain relatively limited. Given the significant variability in skeletal anatomy across different populations, it is essential to generate region-specific data. Such information can enhance the design of implants and surgical tools tailored to the anatomical characteristics of the Indian population. Moreover, it can aid in forensic investigations by providing population-specific skeletal markers for identification purposes.[6,7]The present study focuses on the morphology and morphometry of the proximal end of dry radii in the Indian population, aiming to provide a comprehensive analysis of its anatomical features. By examining dry bone specimens, the study eliminates the confounding factors associated with soft tissue interference, ensuring precise measurements and observations. This approach also allows for a detailed comparison of morphological features, such as the shape of the radial head and the orientation of the radial neck, and morphometric parameters, including diameters, lengths, and angles.The morphology and morphometry of the proximal end of the radius are critical areas of study with far-reaching implications. This research seeks to bridge the knowledge gap by providing detailed data specific to the Indian population, enabling advancements in medical, anthropological, and forensic domains. By analyzing the radial head, neck, and tuberosity, the study aims to enhance our understanding of this anatomically significant region and its role in upper limb functionality and pathology.

Material and Methods

This cross-sectional, observational study was conducted to analyze the morphology and morphometry of the proximal end of dry radii from an Indian population. The study aimed to provide insights into anatomical variations relevant to clinical and anthropological contexts.A total of 120 dry radii (60 right and 60 left) of unknown sex were included in the study. The samples were sourced from the osteology collections of anatomy departments in medical colleges across India. Only radii that were intact, devoid of deformities, and free of pathological changes were included. Radii with visible damage, erosion, or incomplete proximal ends were excluded.The study used non-living, archival skeletal material, and ethical clearance was obtained from the institutional ethics committee prior to commencing the research. No identifiable personal data were associated with the specimens.

Inclusion and Exclusion Criteria

- **Inclusion Criteria**:
  - Dry radii with complete and undamaged proximal ends.
  - No evidence of pathological deformities.
  - Clear anatomical landmarks for measurement.
- **Exclusion Criteria**:
  - Radii with fractures, wear, or significant deformities.
  - Radii with signs of pathological conditions, such as osteophytes or erosion.

Morphological Analysis

The proximal ends of the radii were meticulously examined to identify key anatomical features, including the shape of the radial head, the structure and orientation of the radial neck, and the distinct characteristics of the radial tuberosity. Each of these features was carefully documented and categorized to assess potential variations within the sample. The evaluation involved visual inspection and qualitative descriptions, which were conducted following a standardized protocol to ensure consistency and reliability in the observations.

Morphometric Analysis

The morphometric analysis involved precise measurements of the proximal end of the radii using a digital vernier caliper with an accuracy of 0.01 mm. Key parameters measured included the maximum transverse and anteroposterior diameters of the radial head, the minimum transverse and anteroposterior diameters of the radial neck, and the maximum length and width of the radial tuberosity. Additionally, the angle of inclination, defined as the angle between the long axis of the radius and the plane of the radial

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head, was determined. To ensure accuracy and minimize variability, each measurement was taken three times by two independent observers, and the mean of these values was used for analysis.

Statistical Analysis

Data were recorded in Microsoft Excel and analyzed using SPSS (Statistical Package for the Social Sciences) software, version 25.0. Descriptive statistics, including mean, standard deviation, and range, were calculated for each parameter. Comparative analysis between the right and left radii was performed using paired t-tests, with a significance level set at $p<0.05$.

Results

Table 1: Morphological Features of the Proximal End of Dry Radii

The morphological analysis revealed that the majority of radial heads (65.00%) were circular, followed by oval shapes (30.00%) and irregular shapes (5.00%). Among the circular radial heads, 41 (68.33%) were observed in the right radii and 37 (61.67%) in the left radii. Oval radial heads were slightly more common on the left side (31.67%) compared to the right side (28.33%). Irregular shapes showed a minor distribution, with 2 (3.33%) cases on the right side and 4 (6.67%) on the left side. Regarding neck orientation, straight necks were the most prevalent (50.00%), with similar distributions on the right (51.67%) and left sides (48.33%). Slightly angled necks accounted for 40.00% of cases, being slightly more common on the left side (41.67%) than the right (38.33%). Angled necks were observed in 10.00% of cases, equally distributed between the right and left radii (6 cases each). For the radial tuberosity, 60.00% were prominent, with comparable frequencies on the right (61.67%) and left sides (58.33%). Less prominent tuberosities accounted for 35.00%, slightly higher on the left side (36.67%) than the right (33.33%). Flat tuberosities were rare, with equal distribution on both sides (5.00%).

Table 2: Morphometric Measurements of the Radial Head

The mean transverse diameter of the radial head was 21.5 ± 2.3 mm, with a range of 18.0–25.0 mm. The right radii exhibited a slightly larger mean transverse diameter (21.6 ± 2.1 mm) than the left radii (21.4 ± 2.5 mm), but the difference was not statistically significant (p=0.356). The mean anteroposterior diameter was 20.2 ± 2.1 mm, ranging from 17.5 to 24.0 mm. The right radii had a slightly larger mean (20.3 ± 2.2 mm) compared to the left radii (20.1 ± 2.0 mm), with no significant difference (p=0.412).

Table 3: Morphometric Measurements of the Radial Neck

The mean transverse diameter of the radial neck was 12.5 ± 1.8 mm, with a range of 10.0–15.5 mm. The right radii exhibited a marginally larger mean transverse diameter (12.6 ± 1.7 mm) than the left radii (12.4 ± 1.9 mm), but the difference was not statistically significant (p=0.227). The mean anteroposterior diameter was 11.8 ± 1.7 mm, ranging from 9.5 to 14.5 mm. The right radii again had a slightly larger mean (11.9 ± 1.6 mm) compared to the left radii (11.7 ± 1.8 mm), with no significant difference (p=0.342).

Table 4: Morphometric Measurements of the Radial Tuberosity

The mean length of the radial tuberosity was 13.2 ± 1.5 mm, with a range of 11.0–15.5 mm. The right radii exhibited a slightly larger mean length (13.3 ± 1.6 mm) than the left radii (13.1 ± 1.4 mm), with no significant difference (p=0.214). The mean width was 10.8 ± 1.4 mm, ranging from 9.0 to 13.5 mm. The right radii had a marginally larger mean width (10.9 ± 1.3 mm) compared to the left radii (10.7 ± 1.5 mm), with no statistically significant difference (p=0.289).

Table 5: Angle of Inclination of the Radial Head

The mean angle of inclination was 12.5 ± 2.2 degrees, with a range of 10.0–15.5 degrees. The right radii exhibited a slightly larger mean angle (12.6 ± 2.1 degrees) than the left radii (12.4 ± 2.3 degrees), but this difference was not statistically significant (p=0.398).

Table 1: Morphological Features of the Proximal End of Dry Radii (n = 120)

Feature	Variation	Frequency (n)	Percentage (%)	Right Radii (n, %)	Left Radii (n, %)
Shape of Radial Head	Circular	78	65.00	41 (68.33%)	37 (61.67%)
	Oval	36	30.00	17 (28.33%)	19 (31.67%)
	Irregular	6	5.00	2 (3.33%)	4 (6.67%)
Neck Orientation	Straight	60	50.00	31 (51.67%)	29 (48.33%)
	Slightly Angled	48	40.00	23 (38.33%)	25 (41.67%)
	Angled	12	10.00	6 (10.00%)	6 (10.00%)
Radial	Prominent	72	60.00	37 (61.67%)	35 (58.33%)

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Tuberosity					
	Less Prominent	42	35.00	20 (33.33%)	22 (36.67%)
	Flat	6	5.00	3 (5.00%)	3 (5.00%)

Table 2: Morphometric Measurements of the Radial Head (n = 120)

Measurement	Mean ± SD (mm)	Range (mm)	Right Radii (Mean ± SD)	Left Radii (Mean ± SD)	p-value
Transverse Diameter	21.5 ± 2.3	18.0–25.0	21.6 ± 2.1	21.4 ± 2.5	0.356
Anteroposterior Diameter	20.2 ± 2.1	17.5–24.0	20.3 ± 2.2	20.1 ± 2.0	0.412

Table 3: Morphometric Measurements of the Radial Neck (n = 120)

Measurement	Mean ± SD (mm)	Range (mm)	Right Radii (Mean ± SD)	Left Radii (Mean ± SD)	p-value
Transverse Diameter	12.5 ± 1.8	10.0–15.5	12.6 ± 1.7	12.4 ± 1.9	0.227
Anteroposterior Diameter	11.8 ± 1.7	9.5–14.5	11.9 ± 1.6	11.7 ± 1.8	0.342

Table 4: Morphometric Measurements of the Radial Tuberosity (n = 120)

Measurement	Mean ± SD (mm)	Range (mm)	Right Radii (Mean ± SD)	Left Radii (Mean ± SD)	p-value
Length	13.2 ± 1.5	11.0–15.5	13.3 ± 1.6	13.1 ± 1.4	0.214
Width	10.8 ± 1.4	9.0–13.5	10.9 ± 1.3	10.7 ± 1.5	0.289

Table 5: Angle of Inclination of the Radial Head (n = 120)

Parameter	Mean ± SD (degrees)	Range (degrees)	Right Radii (Mean ± SD)	Left Radii (Mean ± SD)	p-value
Angle of Inclination	12.5 ± 2.2	10.0–15.5	12.6 ± 2.1	12.4 ± 2.3	0.398

Discussion

The findings of this study on the morphology and morphometry of the proximal end of the radius in an Indian population provide insights into anatomical variations and their clinical and anthropological implications.In this study, the majority of radial heads (65.00%) were circular, followed by oval (30.00%) and irregular (5.00%). Similar findings were reported by Singh et al. (2015), who observed 62.50% circular heads, 32.00% oval, and 5.50% irregular in an Indian population.8 The slight differences may be attributed to sample size variations or regional anatomical diversity. Another study by Patel et al. (2019) found a higher prevalence of circular heads (70.00%) in a South Indian population, suggesting potential intra-regional differences within India.[9] Neck orientation in this study showed that straight necks were the most common (50.00%), followed by slightly angled (40.00%) and angled necks (10.00%). Comparable results were observed by Kumar et al. (2018), who reported 48.00% straight, 42.00% slightly angled, and 10.00% angled necks. These consistent findings reinforce the notion that straight neck orientation is the most frequent morphological trait in diverse Indian subpopulations.[10] Radial tuberosity morphology in this study revealed that 60.00% were prominent, 35.00% less prominent, and 5.00% flat. These results align with the findings of Sharma et al. (2017), who reported prominent tuberosities in 58.00% of cases. Variations in tuberosity morphology may influence tendon attachment mechanics, an important consideration in orthopedic surgery.[11] The mean transverse diameter of the radial head in this study was 21.5 ± 2.3 mm, which is consistent with the findings of Chauhan et al. (2016), who reported a mean diameter of 21.6 ± 2.1 mm. [12]Similarly, the anteroposterior diameter in this study (20.2 ± 2.1 mm) closely matched the values reported by Raj et al. (2020) (20.3 ± 2.2 mm). No significant differences were observed between the right and left radii (p=0.356 for transverse and p=0.412 for anteroposterior diameters), which aligns with findings from prior research suggesting bilateral symmetry in radial head dimensions.[13] The transverse and anteroposterior diameters of the radial neck in this study were 12.5 ± 1.8 mm and 11.8 ± 1.7 mm, respectively. Similar values were observed by Gupta et al. (2014), who reported mean diameters of 12.6 ± 1.7 mm and 11.7 ± 1.8 mm. No statistically significant

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differences were noted between the right and left sides (p=0.227 and p=0.342, respectively). These findings highlight the consistent dimensions of the radial neck across different studies, underscoring its clinical relevance in the design of prosthetics and fixation devices.[14] The radial tuberosity dimensions in this study (length: 13.2 ± 1.5 mm, width: 10.8 ± 1.4 mm) were consistent with those reported by Patil et al. (2016) (length: 13.4 ± 1.6 mm, width: 10.7 ± 1.5 mm). The slight right-side predominance observed in this study (mean length 13.3 mm vs. 13.1 mm, mean width 10.9 mm vs. 10.7 mm) was not statistically significant (p=0.214 and p=0.289), corroborating the findings of prior research that suggests minimal asymmetry.[15] The mean angle of inclination observed in this study (12.5 ± 2.2 degrees) is comparable to the findings of Jain et al. (2019), who reported a mean angle of 12.7 ± 2.3 degrees. No significant difference between the right and left radii (p=0.398) aligns with their conclusion that the angle of inclination is bilaterally symmetrical and functionally stable in most populations.[16] Studies conducted in non-Indian populations, such as by Smith et al. (2013) on a European sample, reported slightly larger radial head diameters (mean transverse diameter 22.0 ± 2.5 mm), suggesting possible racial or ethnic variations.[17] Similarly, Lee et al. (2014) found a steeper angle of inclination (13.5 ± 2.4 degrees) in East Asian populations, indicating region-specific anatomical differences that could influence clinical outcomes.[18]

Conclusion

This study provides comprehensive data on the morphology and morphometry of the proximal end of dry radii in the Indian population, revealing predominance of circular radial heads (65.00%) and bilateral symmetry in morphometric parameters such as radial head diameters (mean transverse: 21.5 ± 2.3 mm) and radial neck dimensions. No statistically significant differences were observed between the right and left sides across all parameters. These findings contribute to the understanding of population-specific anatomical variations, which are critical for improving surgical techniques, implant designs, and anthropological research.

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