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Morphological and Morphometric Analysis of the Radius Bone in South Indian Adults: Implications for Surgical Applications and Prosthesis Design

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The radius bone plays a key role in forearm stability, mobility, and load transmission, making its morphometry crucial for surgical and prosthetic applications. This study analysed 61 adult radius bones (33 right, 28 left) from South Indian individuals using SPSS v22.0, revealing minor but significant side differences. The transverse diameter of the radial head and the distal shaft were significantly larger on the right side ($p=0.003$ and $p=0.019$, respectively), likely due to limb dominance. Other parameters showed no notable variation. These findings underscore the importance of population-specific data for improving fracture fixation, implant design, and surgical outcome.

Key words: radius, elbow joint, south Indian adults, orthopaedic anatomy, implant design

Introduction

The radius is a bone situated on the lateral side of the forearm. The name “radius” is derived from the Latin word for ray, reflecting its rotational function around its axis, which extends diagonally from the center of the capitulum to the center of the distal ulna. The radius generally ossifies from three centers: one primary center for the shaft and two secondary centers for the proximal and distal ends [9]. When the forearm is in a supine position, the radius, a long bone, lies on the lateral side. Together with the ulna and carpal bones, the radius plays a key role in enabling extensive dynamic motion at both the elbow and wrist joints. The radius is composed of three main parts:

the proximal end, the shaft, and the distal end. The circular proximal end articulates with the radial notch of the ulna at the radioulnar joint and features a concave articular facet that connects with the capitulum of the distal humerus at the elbow joint. Below the radial head is the radial neck, followed by the radial tuberosity, which is positioned medially and serves as an attachment site for arm muscles [7].

The radius, along with the radioulnar joint, is critical for maintaining the physiological and physical stability of the elbow. Fractures of the hand and wrist account for about 1.5% of all emergency room visits, with radial and ulnar fractures representing 44% of these cases. Fragility fractures of the distal radius are especially common, with a lifetime risk of 15% in women, and are the most frequent initial fracture occurring during the postmenopausal period. In children, distal radius fractures are the most common, accounting for 22.4% of all fractures [10].

The radius and ulna are integral to the pronation and supination of the forearm, which is why the radioulnar joint is considered a "functional joint." A malunited fracture can impair the joint's function and restrict its range of motion. Therefore, it is crucial to restore the correct length, alignment, and rotation of both bones to ensure the forearm's dynamic function remains intact [11]. Considering these factors, understanding the morphological characteristics of the radius bone, particularly in South Indian adults, is essential for improving clinical outcomes and ensuring the optimal function of the forearm and its associated joints.

Materials and Methods

Sixty-three intact adult radius bones (33 right and 28 left) were included, excluding those with incomplete ossification, fractures, or deformities. Morphometric parameters of the proximal and distal ends were measured in supinated and semi-pronated positions and categorized into three regions: proximal radius, radial shaft, and distal radius. For the radial head, circumference, anteroposterior (AP) diameter, transverse diameter, medial height, and lateral height were recorded. Proximal and distal lengths, radial neck diameter, and the head–neck angle in the coronal plane were also noted. The length of the shaft was measured using an osteometric board, while the maximum

Fig. 1. Measurement of radius bone using osteometric board.

and minimum diameters at the proximal and distal thirds, along with the width, length, circumference, and maximum diameter of the bicipital tuberosity, were measured using a digital vernier caliper (accuracy 0.01 mm) and a non-elastic tape.

Statistical Analysis

The statistical analysis was performed using IBM SPSS software, version 22.0. Continuous variables are expressed as mean ± standard deviation (range), while categorical variables are presented as frequencies and percentages. An independent, two-tailed Student's T-test was utilized to assess differences between sides, with a p-value of <0.05 considered statistically significant.

Results

Table 1. Difference between the sides on various parameters of radius:

Variables	Right Side (33)	Left side (28)	p-Value
Length of radius	24.12±1.64	23.96±1.91	0.88
AP measurement of radial head	19.39±1.71	19.02±1.89	0.33
Transverse measurement of radial head	16.13±1.61	15.37±2.24	0.003*
Width of radial tuberosity	11.60±1.28	11.42±1.48	0.494
Length of radial tuberosity	21.44±2.46	21.95±2.98	0.520
Transverse diameter of distal end	26.13±2.07	25.73±2.35	0.138
Articular surface of lunate	9.58±1.04	9.38±0.95	0.208
Articular surface of scaphoid	14.82±1.46	14.90±1.50	0.719
Medial head height	8.30±0.99	8.56±0.91	0.416
Lateral head height	4.55±0.76	4.35±0.64	
Neck length	11.10±2.09	11.19±2.16	0.653
Neck Width P	14.63±1.92	14.74±1.91	0.929
Neck Width D	13.43±1.53	13.24±1.28	0.457
Radial shaft diameter proximal	12.32±1.24	12.11±1.31	0.317
Radial shaft diameter distal	15.43±1.61	14.36±1.37	0.019

The morphometric comparison between the right and left adult radius bones (**Table 1**) revealed that most parameters did not show statistically significant differences, indicating general bilateral symmetry. The length of the radius, anteroposterior (AP) and transverse measurements of the radial head, dimensions of the radial tuberosity, distal end diameters, and articular surface measurements were largely comparable between the sides. However, two parameters demonstrated statistically significant differences.

The transverse diameter of the radial head was significantly greater on the right side (16.13 ± 1.61 mm) compared to the left (15.37 ± 2.24 mm), with a p-value of 0.003, indicating a notable side difference possibly due to functional dominance. Similarly, the distal radial shaft diameter was significantly larger on the right (15.43 ± 1.61 mm) than the left (14.36 ± 1.37 mm), with a p-value of 0.019. These findings suggest subtle morphological asymmetry, likely attributable to habitual use and biomechanical stress on the dominant limb. Other parameters, such as the neck dimensions, proximal radial shaft diameter, and articular surface measurements of the lunate and scaphoid, did not vary significantly, supporting a general morphological consistency across sides in the South Indian adult population.

Discussion

The treatment of displaced and comminuted radial bone fractures often involves internal fixation using plates and screws or reconstructing the radial head. To assess the anatomical features of the radius bone, techniques such as computed tomography, radiography, and cadaveric studies are commonly utilized [10]. Approximately one-third of all elbow fractures are attributed to radial head fractures [2]. Accurate morphometric measurements are essential for the proper reduction of distal radius fractures. Orthopedic surgeons commonly rely on the reference values established by Gartland and Werley [5]. Nevertheless, it is important to note that morphometric parameters can vary due to factors like geographic location, ethnicity, racial differences, and individual physical characteristics [1].

Knowledge of the radial head's size and shape is critical for developing effective radial head prostheses, as these factors play a pivotal role in ensuring successful replacements. Similarly, understanding the parameters of the distal radius is necessary for creating prostheses for cases like Colles' fractures, while the size and shape of the radial tuberosity are particularly important in procedures like bicipital tendon reconstruction [9].

Distal radial fractures are commonly caused by trauma to the forearm. These fractures can include Smith's, Colles', Torus/Buckle, Greenstick, Die-punch, and isolated radial shaft fractures [3]. The incidence of radial fractures is increasing with the rise in life expectancy, resulting in a growing population of patients at risk for these injuries. Such fractures are predominantly observed in children, adolescents, and the elderly [4].

The current study shows that the AP measurement of the radial head (19.39 ± 1.71 mm on the right and 19.02 ± 1.89 mm on the left) is consistently larger than the transverse measurement (16.13 ± 1.61 mm on the right and 15.37 ± 2.24 mm on the left), indicating an elongated anteroposterior profile and a natural asymmetry favoring the AP diameter. These findings align with those of Kuhn et al., who also reported a greater AP diameter compared to the transverse diameter, emphasizing its functional significance in maintaining joint stability and load distribution during forearm movements [6]. Similarly, Reddy et al. observed a larger AP diameter relative to the transverse diameter, though their study highlighted variability based on population and handedness, with their measurements indicating slightly larger overall dimensions than those found in the current study [10].

In this study, the width of the radial tuberosity was measured as 11.60 ± 1.28 mm on the right and 11.42 ± 1.48 mm on the left, while the length was 21.44 ± 2.46 mm on the right and 21.95 ± 2.98 mm on the left, showing minimal differences between the sides. Comparatively, Rajashree et al. reported slightly larger dimensions for the radial tuberosity in their study, with the width and length both exceeding the values observed in this study [8].

The study underscores the importance of morphometric analysis of the radius for surgical applications, particularly in prosthesis and fixation device design. Variations in radial head and tuberosity measurements suggest the need for personalized approaches in orthopedic care. These findings can enhance surgical precision and patient outcomes. However, the study is limited by the small sample size and the failure to account for soft tissue variations, which may influence the results.

Conclusion

In conclusion, the findings of this study underscore the importance of detailed morphometric analysis of the radius bone, particularly the radial head and tuberosity, for clinical and surgical applications. The observed variations in anteroposterior and transverse dimensions, as well as side-specific differences in radial tuberosity measurements, highlight the need for individualized approaches in the design and selection of prostheses and fixation devices. These measurements also emphasize the functional significance of the radial head's elongated anteroposterior profile in ensuring joint stability and effective load distribution. Furthermore, the variability reported across different populations and studies underscores the necessity of accounting for geographic, ethnic, and individual factors in orthopedic practice. Such comprehensive morphometric data can aid in the refinement of surgical techniques, enhance the accuracy of fracture reduction, and improve the outcomes of reconstructive procedures, ultimately contributing to better patient care.

Limitations and Future Scope:

The study is limited by sample size and absence of gender-specific data. Future research with larger cohorts and advanced imaging may provide more accurate measurements and broader population comparisons.

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