A Morphological and Morphometric Study of Proximal and Distal Ends of Dry Radii with its Clinical Implications

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Background: Knowledge of the size and shape of radial head is essential for construction of radial head prosthesis. Further, the measurements of bicipital tuberosity and its angular relationship to radial head are significant in surgical techniques, like in the reconstruction of biceps tendon. Even the morphometry of the distal radius is significant in numerous clinical orthopedic situations such as reduction of distal radius fractures and in the design of distal radius prosthesis. So, the aim of the study was to determine the morphometric parameters of proximal and distal radius in dry adult Indian radius.

Methods: Fifty intact adult Indian radius (right = 23, left = 27) were chosen, and the various parameters of proximal and distal ends of radius were studied. Student's *t*-test was done to correlate all these parameters on the right and left sides.

Results: The mean length of radius, height of head at medial and lateral ends, head anteroposterior and transverse diameter, head thickness at ventral, dorsal, and lateral ends were 23.5, 0.90, 0.75, 1.91, 1.85, 0.42, 0.32, and 0.30 cm, respectively. The mean depth of articular facet, length of neck, proximal and distal neck diameter, width and length of bicipital tuberosity, and radial circumference at bicipital tuberosity were 0.19, 1.19, 1.36, 1.31, 1.23, 1.97, and 4.54 cm, respectively. The mean length of styloid process, oblique and transverse width of lower end, anteroposterior diameter of lower end, and angle of radial inclination were 0.98cm, 2. 81cm, 2.59cm, 1.86cm, and 25.05º, respectively.

Conclusion: This study will be useful for orthopedic surgeons in making prosthesis for the proximal and distal ends of radius.

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Key words: angle of inclination, head, neck, prosthesis, radius

At a Glance Commentary

Scientific background of the subject

Nowadays fractures of radial head and neck are more common. Surgical management of displaced and comminuted radial head fractures needs replacement with radial head prosthesis if reconstruction is not possible.

What this study adds to the field

The results of our study are important in making anatomically and biomechanically correct radial head as well as the distal end of radius prosthes is. In our study, we looked for the prevalence of types of curvature at the head and neck zone, which is important for the surgeon to select the most appropriate plate and to achieve good anatomical restoration of the proximal radius. The dimensions of the bicipital tuberosity will facilitate in various surgical procedures such as reconstruction of the distal biceps tendon.

Radial head and neck fractures constitute 1.7–5.4% of all fractures. Radial head fractures alone constitute one-third of all elbow fractures and about 20% of all elbow trauma cases.[1] An appreciation of the part played by radial head in the overall stability of elbow and forearm has encouraged several investigators to recommend conservation of radial head, either by operative fixation or by prosthetic replacement.

Distal radius fractures comprise 8–15% of all upper limb fractures. So, information of normal values of distal

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morphometry is significant, as one of the goals of management for fractures is to reestablish anatomical configuration.[2] The quality of reduction is evaluated chiefly by the degree of restoration of radial angle of inclination and palmar tilt.[3] Radial shortening, increased radial inclination, and dorsal angulation cause substantial modifications in the kinematics of the wrist joint and grip strength. Even pronation and supination are associated with the initial length of radius and dorsal angulation.[4-6]

So, the aim of the study was to determine the morphometric parameters and the morphology of head, neck, bicipital tuberosity, and the distal end of dry radius in South Indian population.

METHODS

Fifty intact adult radius (right = 23, left = 27) were chosen, and the bones with incomplete ossification, previous fracture, or deformity were excluded from the study. Various parameters of proximal and distal end of radius were measured in supinated as well as semi-pronated position of radius [Figures 1–5]:

- Length of radius (L)- The radial length was measured as the distance between the tip of radial styloid and the most lateral portion of the radial head
- Height of radial head in medial (MH) and lateral (LH) sides- The medial and lateral height of the radial head was measured as the distance between the radial lip and the head–neck border
- Anteroposterior diameter (APD and transverse diameters (TD) of the radial head
- Thickness of ventral (TVC), lateral (TLC), and dorsal (TDC) curves
- Depth of articular facet (D)
- Prevalence of types of shapes of the radial head
- Length of neck of radius (NL)- The neck length was measured as the distance between the head–neck border and the superior border of bicipital tuberosity
- Proximal radial neck diameter (PND) and distal radial neck diameter (DND)- Proximal and distal radial neck diameter was measured lateromedially
- Prevalence of types of curvature at the head and neck zone- Types of curvature were classified as flat profile and low concave curvature
- Width of bicipital tuberosity (WBT)
- Length of bicipital tuberosity (LBT)
- Circumference of radius at bicipital tuberosity (CRBT)- Circumference at radial tuberosity was taken at the maximum convexity of radial tuberosity and this was measured with the help of a measuring tape
- Prevalence of morphological variants of bicipital tuberosity- Morphological variants of bicipital tuberosity were classified as smooth, a single ridge, or bifid ridge
- Angle of radial inclination- The angle of radial inclination was measured as the angle between a line joining the tip of radial styloid and the medial edge of the distal end of radius and a line perpendicular to the long axis of the radius
- Length of radial styloid (SL) process- Length of radial styloid was measured as the distance between the tip of radial styloid and a perpendicular to the long axis of the radius at the level of the medial edge of distal radius
- Widths of distal radius oblique (WDO) and transverse (WDT)- WDT was measured as the maximum width of the distal radius along a perpendicular to the

Figure 1: Various measurements done on radius: (A) length of radius, (B) height of radial head at its medial end, (C) transverse diameter of head, (D) AP diameter of head.

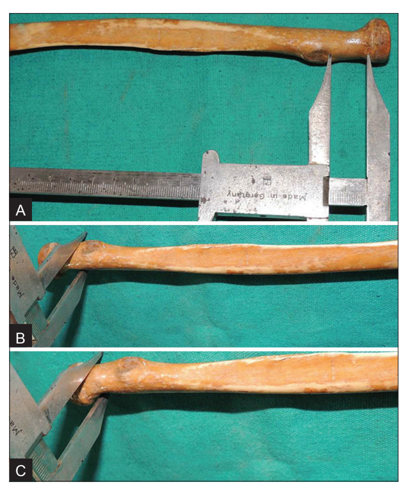

Figure 2: Various measurements done on radius: (A) length of radius neck, (B) distal neck diameter, (C) proximal diameter of neck.

long axis of the radius, at the level of the medial edge of radius. WDO was measured as the oblique width of the radius along its distal margin

- Anteroposterior diameter (APD de) of distal end.

All these measurements were taken with the help of vernier caliper. Angle of inclination was measured with the help of a protractor. Student's *t*-test was used to correlate all these parameters on the right and left sides. Data were analyzed using IBM SPSS Statistics for Windows version 20.0, USA.

RESULTS

The mean and range of all parameters of the right and left radii are shown in Tables 1 and 2.

The mean length of radius, height of the radial head at medial and lateral ends, head AP, transverse diameter, head thickness at the ventral, dorsal, and lateral sides, and depth of articular facet in total radius were 23.5, 0.9, 0.75, 1.91, 1.85, 0.42, 0.32, 0.30, and 0.19 cm, respectively.

The mean neck length, proximal and distal neck diameter, width and length of bicipital tuberosity, radial circumference at bicipital groove, length of styloid process, oblique and transverse width of lower end, and AP diameter of lower end in total radius were 1.19, 1.36, 1.31, 1.23, 1.97, 4.54, 0.98, 2.81, 2.59, and 1.86, respectively.

The mean angles of radial inclination in our study in total, right radius, and left radius were 25.05º, 24.5º, and 25.6º, respectively.

Most common shape of radial head in our study was circular in 32 radii (64%) out of total 50 radii [Figures 6 and 7]. In our study, we had two types of curvatures between neck and head of radius; they were flat and low concave and both were equal in frequency, i.e. 50%.

In our study, we found single ridge on bicipital tuberosity most commonly (i.e. in 60% of cases) [Table 3].

In our study, there was no significant correlation in any parameter of radius on both right and left sides, as the $p > 0.05$.

Figure 3: Various measurements done on radius: (A) length of bicipital tuberosity, (B) width of bicipital tuberosity, (C) circumference of radius at bicipital tuberosity.

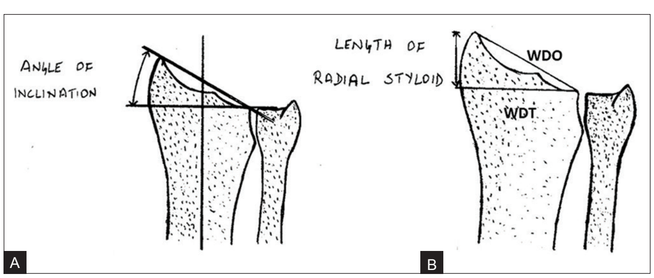

Figure 5: Various measurements done on distal end of radius: (A) angle of inclination, (B) length of styloid process (WDO- oblique width of distal end, WDT- transverse width of distal end).

Figure 4: Morphological features of radius: (A) oval head, (B) irregular head, (C) round head, (D) smooth bicipital tuberosity, (E) single ridge on bicipital tuberosity, (F) bifid ridge on bicipital tuberosity.

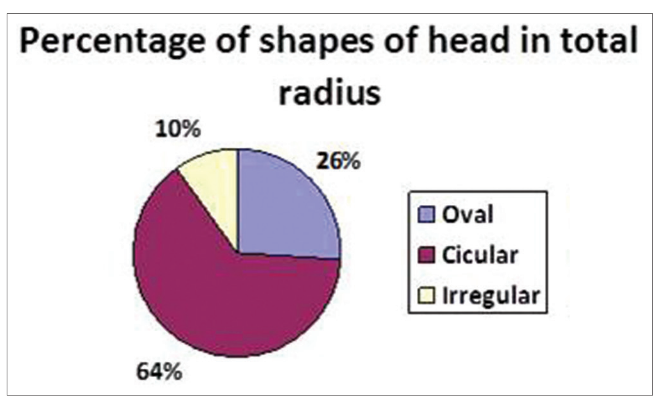

Figure 6: Various shapes of radial head in right, left, and total radius.

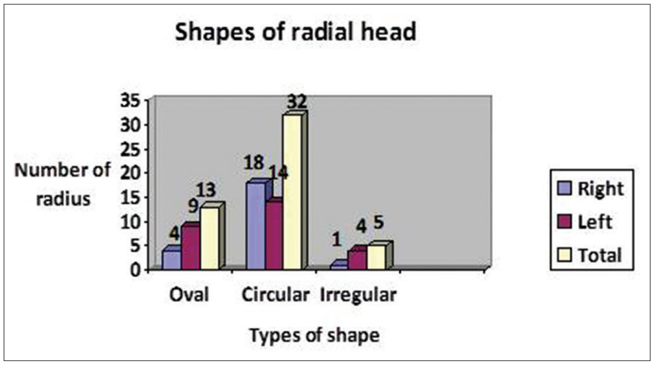

Figure 7: Percentage of various types of shapes of radial head in total radius.

Table 1: Mean and range of all parameters of radius on the right and left sides

Parameters	Mean±SD (cm)	Range (cm)
Length of radius		
Right	23.98±1.6	21-27
Left	23.12±2.11	20-27.40
Height of radial head at medial end		
Right	0.91±0.10	0.70-1.10
Left	0.90±0.13	0.70-1.10
Height of radial head at lateral end		
Right	0.73±0.09	0.60-0.90
Left	0.77±0.14	0.40-1
Head AP diameter		
Right	1.96±0.18	1.50-2.30
Left	1.87±0.21	1.50-2.40
Head transverse diameter		
Right	1.89±0.21	1.50-2.30
Left	1.82±0.21	1.40-2.20
Head thickness ventral		
Right	0.43±0.05	0.30-0.50
Left	0.41±0.081	0.30-0.70
Head thickness dorsal		
Right	0.32±0.06	0.20-0.50
Left	0.32±0.075	0.20-0.50
Head thickness lateral		
Right	0.33±0.10	0.20-0.50
Left	0.28±0.094	0.10-0.40
Depth of articular facet		
Right	0.2±0.06	0.10-0.30
Left	0.19±0.051	0.10-0.30
Neck length		
Right	1.18±0.25	0.70-1.90
Left	1.20±0.31	0.70-2.10
Proximal neck diameter		
Right	1.36±0.22	1-1.80
Left	1.35±0.16	1.10-1.70
Distal neck diameter		
Right	1.33±0.19	1-1.70
Left	1.29±0.19	1-1.80

DISCUSSION

Operative treatment of displaced and comminuted radial head fractures requires internal fixation with plates and screws in cases where reconstruction can be done and replacement with a radial head prosthesis when the radial head is unreconstructable.[7] Some biomechanical studies have emphasized the importance of correctly sizing the radial head prosthesis at the time of implantation.[8] In unstable elbow fractures, accurate implant size is a significant factor to prevent subluxation of the radial head.[7]

Puchwein *et al*.[7] and Captier *et al.*[9] found the mean AP diameter of the radial head at its widest part as 2.3 and 2.16 cm, respectively, and in the transverse plane as 2.24 and 2.1 cm, respectively, while in our study, we got the values as 1.91 and 1.85 cm, respectively. Puchwein *et al.* also found the mean radial head length on medial and lateral sides as 1.17 and 1.18 cm, respectively, while in our study we got the values as 0.9 and 0.75 cm, respectively.[7] Our values are less than those reported by Puchwein *et al*., which may be because they measured the values on CT scan and we did it on dry bone.

Captier *et al.* also found that the radial head was elliptical in 57% of cases and circular in 43% of cases, but in our study we got the most common shape as circular in 64% of cases, oval in 26%, and irregular in 10% of cases. They also found that biomechanics of the circular shape and elliptical shape are different, involving an adaptation of the angle between the neck and the radial diaphysis. This modification must be taken into concern in the design of radial head prosthesis.[9]

Van Riet *et al.* found the mean radial length as 23.5 cm and the mean radial neck length as 1.3 cm, and we also got similar values in our study (23.5 and 1.19 cm, respectively).[10]

Swieszkowski *et al.* found the mean depth of articular facet as 0.19 cm, and we also got similar value in our study (0.19 cm).[11]

Mazzocca *et al.* found the mean length and width of bicipital tuberosity as 2.2 and 1.5 cm, respectively. They also found that the bicipital tuberosity ridge was smooth in 6% of specimens, bifid in 6%, and the remaining 88% of specimens had a single ridge.[12] In our study, we found the mean length and width of bicipital tuberosity as 1.97 and 1.23 cm, respectively. Our values were slightly less than theirs. In our study also, we found mainly single ridge on bicipital tuberosity (in 60% of cases); we also found smooth bicipital tuberosity in 36% of cases and bifid in 4% of cases.

Prithishkumar *et al.* found the mean radial inclination as 21.8° on the left side and 22.1° on the right side. They found the mean length of radius, length of radial styloid

Table 2: Mean and range of all parameters of radius on the right and left sides

Parameters	Mean±SD	Range
Width of bicipital tuberosity		
Right	1.25±0.15	1-1.60
Left	1.21±0.19	1-1.70
Length of bicipital tuberosity		
Right	2.02±0.29	1.20-2.60
Left	1.92±0.35	0.80-2.80
Radial circumference		
Right	4.65±0.45	3.70-5.60
Left	4.45±0.48	3.70-5.40
Length of styloid process		
Right	1±0.13	0.80-1.20
Left	0.97±0.14	0.70-1.20
Oblique width of lower end		
Right	2.83±0.21	2.40-3.30
Left	2.78±0.23	2.40-3.20
Transverse width of lower end		
Right	2.64±0.22	2.10-3.10
Left	2.55±0.27	2-3.10
AP diameter of lower end		
Right	1.89±0.21	1.60-2.30
Left	1.84±0.22	1.50-2.40

Table 3: Different types of morphological variants of bicipital tuberosity

Morphological variants of bicipital tuberosity	Single ridge	Smooth	Double ridge
Right	14	7	2
Left	16	11	0
Total	30 (60%)	18 (36%)	2 (4%)

process, transverse and oblique width of distal end, and the AP diameter of distal end as 24.4, 1.1, 2.67, 2.72, and 1.78 cm, respectively, on the left side and 24.2, 1.08, 2.63, 2.67, and 1.75 cm, respectively, on the right side.[13] In our study, we found the angle of radial inclination as 25.6° on the left side and 24.5° on the right side. Our values were slightly higher than theirs. We found the mean length of radius, length of radial styloid process, transverse and oblique width of distal end, and the AP diameter of distal end as 23.12, 0.97, 2.55, 2.78, and 1.84 cm, respectively, on the left side and 23.9, 1.0, 2.64, 2.83, and 1.89 cm, respectively, on the right side. Our values were almost similar to their values.

Chan *et al.*, Gartland and Werley, Schuind *et al.,* and Werner *et al.* found the mean value of radial inclination as 25.1°, 23°, 24°, and 30°, respectively.[14-17] In our study, we got the angle of radial inclination as 25.05°, which was almost similar to the values obtained by Chan *et al.*, Gartland and Werley, and Schuind *et al*.

These dimensions of the bicipital tuberosity, radial head, and radial styloid process will facilitate in various surgical procedures such as reconstruction of the distal biceps tendon, radial head prosthesis implantation, and reconstruction of proximal radius trauma.[12]

New modular designs have enhanced sizing to better replicate the anatomy of the proximal radius, and they are easier to insert intraoperatively.[18] Smith *et al.* found that the "safe zone" is approximately one-third of the radial head circumference and can be reliably determined with the technique of intraoperative marking as delineated.[19]

Giannicola *et al.* found that the outline of the proximal radius in the safe zone displays extensive morphologic dissimilarities that should be taken into account when operating on fractures of the proximal radius, to prevent malunions, pain, and stiffness of the elbow joint. They are also of the opinion that osteosynthesis of radial head and neck fractures should be done in safe zone, where a plate can be securely applied without risking the proximal radioulnar joint.[20]

In our study, we also looked for prevalence of types of curvature at the head and neck zone and we classified the curvature as flat or low concave. Also, in our study, both flat and low concave were equal in frequency, i.e. 50%. Knowledge of the proper bending radius of the safe zone allows the surgeon to select the most appropriate plate and to achieve good fracture reduction and anatomical restoration of the proximal radius.[20]

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