

Original Research Article

Morphometry and morphology of radial head: implications for prosthetic design and arthroplasty

Rimple Bansal, Usva Kawoosa, Muneer Ahmad Zaz, Ruchi Goyal*, Gurdeep Singh Kalyan

Department of Anatomy, Government Medical College, Patiala, Punjab, India

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*Correspondence:

Dr. Ruchi Goyal

E-mail: dr.roochie@yahoo.com

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ABSTRACT

Background: Sufficient knowledge of various parameters of the radius head plays a cardinal role in various pathological conditions pertaining to radius be that reduction of fractures, designing its prosthesis, its knowledge is substantial in various such conditions. Current study was designed aiming to determine the morphometric & morphological parameters of adult human radii head in North Indian population.

Methods: 100 adult radii (50 from right and 50 from left) were studied.

Results: The mean weight of right radius bone was more on the left side while the mean values of total length of radius, medial length and lateral length were found to be more of right radii. The shape of radial head was found to be mostly circular. Strong significant correlation was found when total length of radius was compared with anteroposterior diameter of head ($r=0.63$, $p<0.05$), transverse diameter of head ($r=0.66$, $p<0.05$) and head circumference of radius ($r=0.62$, $p<0.05$). Very strong significant correlation between anteroposterior diameter and transverse diameter of radius head was seen ($r=0.84$, $p<0.05$).

Conclusions: Current study advocates the importance of alignment of the morphology and morphometry of the radius head while treating several conditions related to it.

Key words: Morphometric, Morphological, Radii head

INTRODUCTION

Radius head is discoid proximally with a shallow cup for articulation with humeral capitulum. The smooth articular periphery is vertically deepest, where it contacts the ulnar radial notch. The posterior surface is palpable in a small depression on the lateral side of the back of the extended elbow. The proximal articular surface of the radial head and its circumference are covered by hyaline cartilage. Joint formed at proximal end includes elbow joint, proximal radio-ulnar joint.¹

The humero-radial joint (elbow joint) permits flexion and extension movements at elbow joint and superior radio-ulnar joint permits supination and pronation movements of forearm. That is why proximal end of radius is very important clinically.¹ The fractures of proximal end of

radius are approximately 1.7% to 5.4% of all fractures² and about 1/5th of all fractures at elbow forming about 20%.³ Individuals between the age of 30 – 40 years have 20% of elbow injuries particularly radial head fractures being more common in women than men.⁴

Knowledge of size and shape of radial head is necessary for creation of anatomically and biomechanically correct radial head prosthesis. The difference in biomechanics of circular shape and the elliptical shape of radial head must be taken in consideration in design of radial head prosthesis.⁵ The head of radius is fundamental element for the physiological or prosthetic stability of the elbow and superior radio ulnar joint and participates with the fovea radialis in elbow flexion and with radial head circumference in pronation -supination.³

The radial head fracture can lead to significant upper extremity disability. A comminuted radial head fracture with a medial collateral ligament tear presents a clinical enigma.⁶ Radius fractures are most common fractures of upper extremity. Treatment of radial head fractures are immobilization, excision with or without prosthetic replacement, open reduction and internal fixation. Sometimes due to valgus forced injury to elbow, fracture of proximal end of radius complicate with the fracture of olecranon process of ulna. Prosthetic replacement of radial head has been suggested after excision of comminuted fracture of radial head.⁴ Radial head prosthesis must restore maximum function of radial head within the elbow joint along with the correct positioning, load bearing and stability.³

Restoration of the anatomical situation can only be achieved when the implant is placed in the correct position, even with a perfectly created anatomical prosthesis.⁷ The complex anatomy of radius, the availability of new intra and extra medullary implants, the increased incidence of iatrogenic injuries seek a special focus on more detailed morphometric and morphologic study of radius. So current study is designed pertaining to such parameters of radius.

METHODS

A descriptive cross-sectional study conducted on total of 100 cadaveric dry radii (50 bones of right side and 50 bones of left side) of unknown age and sex available in the Department of Anatomy of our Institute. The radii which were dry, fully ossified, complete in all aspects, free from any pathology like fractures, old unhealed fractures, visible deformity or growth were included in the study to ensure data authenticity. All measurements were performed by a single trained observer and to maintain consistency and minimize interobserver variability. The measurements were meticulously recorded, compiled, scrutinized, analysed and reviewed in light of accessible literature. All the measurements were compiled on excel white spread sheet.

Weight of radius of the bone was taken in grams, using a digital weighing scale. Total length (between proximal aspect of head of radius and most distal aspect of styloid process), length of radius on medial aspect (between the medial aspect of radial head above and the lower border of the ulnar notch below) and length of radius on lateral aspect (between the lateral aspect of head above and edge of the styloid process below) were noted (Figure 1a).

Radial head shape, curvatures (at head and neck zone curvatures) were noted. Length of radial head on lateral aspect (between the upper border of lateral aspect of the head above and lower border of the lateral aspect of head below) and on medial aspect (from the upper border of medial aspect of radial head above and lower border of medial aspect of head) were studied (Figure 1b).

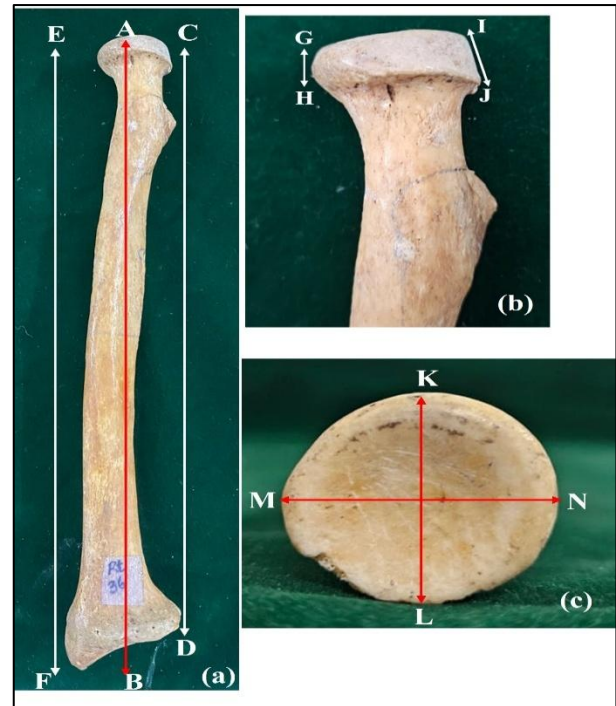


Figure 1: (a) Total length (AB), length of radius on medial aspect (CD) and length of radius on lateral aspect (EF); (b) Length of radial head on lateral aspect (GH) and on medial aspect (IJ); (c) Anteroposterior diameter (KL) and transverse diameter (MN).

Anteroposterior diameter (from most anterior point on radial head to most posterior point), transverse diameter (from medial point on radial head to the most lateral point) (Figure 1c) and circumference of radial head were measured. (Figure 2a) Depth of superior articular facet (by putting the scale over radial head touching most prominent anterior and posterior rim of radial head and depth in centre) was measured (Figure 2b).

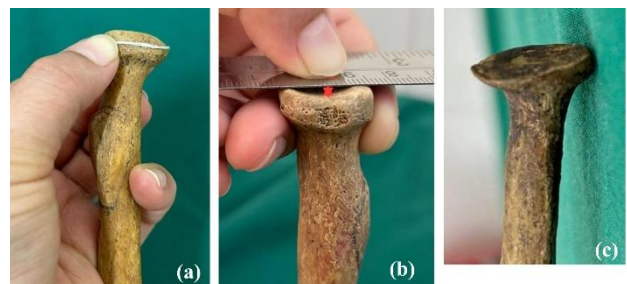


Figure 2: (a) Circumference of radial head; (b) Depth of superior articular facet; and (c) radial head thinning.

Statistical analysis

The calculations were done using SPSS software and statistical analysis was done using paired t-test, correlation coefficient, 95% Confidence Interval. A value of $p < 0.05$ was considered statistically significant.

RESULTS

The mean weight of radius on left side was 40 ± 9.1 grams (16.16-58.26 grams) and on right side was 37.38 ± 9.5 grams (17.09-54.45 grams). The values were more on the left side but the difference between the two sides was statistically insignificant.

The mean values of total length of radius, medial length and lateral length were found to be more of right radii but the difference was statistically insignificant (Table 1).

The shape of radial head was found to be circular in 45(90%) radii and oval in 5(10%) radii of left side and circular in 44(88%) radii and oval in 6(12%) radii of right side. Two types of curvatures between head and neck of radius were noted. Low concave curvature of radial head was found in 85% ($n=43$ left; $n=42$ right) radii followed by flat which was seen in 15% ($n=7$ left; $n=8$ right) radii.

There was no statistically significant relation seen in any of the parameters of radial head of both left and right radial (Table 2).

Table 1: Length of radius.

Length	Left	Right	P value	Total (left + right)
	Mean $\pm$ SD (Range) (cm)	Mean $\pm$ SD (Range) (cm)		Mean $\pm$ SD
Total length	23.8 ± 1.7 (19.2-27.7)	24.1 ± 2 (19.6-27.9)	0.46	23.96 ± 1.84 (23.59- 24.32)
Medial length	22.9 ± 1.7 (18.3-26.6)	23 ± 2 (18.6-26.8)	0.32	22.96 ± 1.81 (22.60-23.32)
Lateral length	23.8 ± 1.7 (19.2-27.7)	24.1 ± 2 (19.6-27.9)	0.47	23.96 ± 1.85 (23.60-24.32)
Total length	23.8 ± 1.7 (19.2-27.7)	24.1 ± 2 (19.6-27.9)	0.46	23.96 ± 1.84 (23.59- 24.32)
Medial length	22.9 ± 1.7 (18.3-26.6)	23 ± 2 (18.6-26.8)	0.32	22.96 ± 1.81 (22.60-23.32)

Table 2: Various morphometric parameters of radial head.

Radial head	Left	Right	P value	Total (Left + Right)
	Mean $\pm$ SD (Range) (mm)	Mean $\pm$ SD (Range) (mm)		Mean $\pm$ SD (95% Confidence Interval) (mm)
Lateral length	7.02 ± 1.23 (4.4-10.46)	7.22 ± 1.23 (7.61-12.03)	0.55	7.12 ± 1.33 (6.86- 7.38)
Medial length	9.5 ± 1.6 (5.66-12.92)	9.04 ± 1.59 (5.61-13.13)	1.52	9.27 ± 1.62 (8.96-9.59)
Antero-posterior diameter	18.9 ± 2 (12.98-21.9)	19.03 ± 1.74 (14.71-22.64)	0.74	18.97 ± 1.89 (18.60-19.33)
Transverse diameter	18.16 ± 1.84 (12.8-22.83)	18.44 ± 1.86 (14.41-22.68)	0.46	18.30 ± 1.87 (17.93- 18.67)
Circumference (cm)	6.7 ± 0.7 (4.6-8.1)	6.73 ± 0.66 (4.9-7.9)	0.58	6.68 ± 0.68 (6.55- 6.82)
Depth	1.97 ± 0.56 (0.38-3.08)	2.1 ± 0.56 (0.86-3.16)	0.16	2.09 ± 0.54 (1.99-2.20)

Table 3: Comparison of various lengths of radius with previous studies.

Authors	Total length mean $\pm$ SD (cm)	Total length mean $\pm$ SD (cm)	Medial length mean $\pm$ SD (cm) lateral length mean $\pm$ SD (cm)		Lateral length mean $\pm$ SD (cm)	
	Left	Right	Left	Right	Left	Right
Prithishkumar et al ¹¹	24.4 ± 16.5	24.2 ± 17.4	-	-	-	-
Gupta et al ¹²	23.12 ± 2.11	23.98 ± 1.6	-	-	23.12 ± 2.11	23.98 ± 1.6
Kumar et al ¹³	23.35 ± 1.75	23.72 ± 1.93	-	-	-	-
Rayna et al ¹⁰	23.4 ± 1.27	23.7 ± 1.30	22.5 ± 1.24	22.7 ± 1.26	23.4 ± 1.27	23.7 ± 1.30
Mittal et al ⁸	23.8 ± 15.1	24.1 ± 15.3	-	-	23.8 ± 15.1	24.1 ± 15.3
Current Study	23.8 ± 1.7	24.1 ± 2	22.9 ± 1.7	23 ± 2	23.8 ± 1.7	24.1 ± 2

Two radial heads one on each side were thinned out (Figure 2c) and therefore length of radial head on lateral side as well as head depth were absent in these two radii. Strong significant correlation was found when total

length of radius was compared with anteroposterior diameter of head ($r=0.63$, $p<0.05$), transverse diameter of head ($r=0.66$, $p<0.05$) and head circumference of radius ($r=0.62$, $p<0.05$). Very strong significant

correlation between anteroposterior diameter and transverse diameter of radius head was seen ($r=0.84$, $p<0.05$) and it was observed that since most of the shape of radial head was circular, the anteroposterior diameter and transverse diameter were same while anteroposterior diameter was more than transverse diameter where radial head was oval.

DISCUSSION

Detailed analysis of radial head could help in the better diagnosis and providing reference data for anatomical reconstructions or alignment for treating various injuries or fractures related to radius and reduce surgical complications post fractures of this region, and can serve as a future reference.

On comparing with the studies done by Mittal et al and Singh et al in Indians and Captier et al in French reported almost similar values for the weight of radius.^{8,9,4}

Comparison of different lengths of radius with earlier studies done by different Indian researchers shows almost similar results. Only Rayna et al had studied medial length of radius.¹⁰ The findings of this study are in consonance with them (Table 3).

In current study 89% of radii showed circular shape which was in consonance with Gupta et al and Ethiraj et al in Indian population, contrary to that Captier et al in French population found elliptical shape as the most common.^{12,14,4} The biomechanics of the circular and the elliptical shape are different, involving an adaptation of the angle between the neck and the radial diaphysis. It becomes mandatory to know the exact shape of radial head and the difference must be considered for designing the radial head prosthesis.⁴

The results demonstrated two types of curvatures between head and neck of radii. Low concave curvature was found in 85% radii whereas in 15% radii no curvature was seen and taken as flat. Contrary to that Gupta et al found both types as 50%.¹²

In current study, lateral length of radial head was supporting the findings of most of the previous studies. However, lower values were reported by Singh and Singh in South Indian population.¹⁵ Measurements of medial length were consistent with the findings of Gupta et al, Singh and Singh, Ethiraj et al and Akshaya and Sangeetha¹⁶ whereas higher values were reported by Reddy et al who conducted the research on fresh frozen cadavers of South India (Table 4).^{12,15-17}

Table 4: Comparison of various morphometric parameters of radial head with previous studies.

Authors	Lateral Length (radial head)		Medial Length (radial head)	
	Left Mean $\pm$ SD (mm)	Right Mean $\pm$ SD (mm)	Left Mean $\pm$ SD (mm)	Right Mean $\pm$ SD (mm)
Gupta et al ¹²	7.7 $\pm$ 1.4	7.3 $\pm$ 0.9	9 $\pm$ 1.3	9.1 $\pm$ 1
Singh and Singh ¹⁵	6.10 $\pm$ 0.95	6.40 $\pm$ 1.17m	9.57 $\pm$ 1.40	7.99 $\pm$ 1.39
Ethiraj et al ¹⁴	7.3 $\pm$ 0.88	7.1 $\pm$ 0.72	9.5 $\pm$ 1.2	8.6 $\pm$ 1
Akshaya and Sangeetha ¹⁶	7.3 $\pm$ 1.13	0.89 $\pm$ 2.93	0.82 $\pm$ 1.87	0.92 $\pm$ 0.90
Reddy et al ¹⁷	7.97 $\pm$ 1.05	8.07 $\pm$ 1.18	10.58 $\pm$ 1.26	11.12 $\pm$ 1.06
Current study	7.02 $\pm$ 1.23	7.22 $\pm$ 1.23	9.5 $\pm$ 1.6	9.04 $\pm$ 1.59

The values of the current study were in consonance with previous studies with respect to mean anteroposterior diameter and mean transverse diameters of left and right radial heads and side predilection on South Indian population done by different authors. However, Reddy et al found higher values which may be attributed to their study done on fresh frozen cadavers.¹⁷ No significant difference between the anteroposterior diameter and transverse diameter was observed. This equality means that the radial head occupies the same volume between the radial notch of the ulna and the annular ligament in neutral position (anteroposterior diameter in transverse

position) and in complete supination (anteroposterior diameter in sagittal position).⁴ On comparing circumference and depth of radial head parameters were in consonance with Rayna et al (Left= 6.1 $\pm$ 0.58 cm and Right= 6.3 $\pm$ 0.60 cm) in Indian population, whereas low values were seen by Avnioglu et al (Left= 5.54 cm and Right= 5.48 cm) in Turkish population and higher values were seen by Reddy et al in South Indian population done on fresh frozen cadavers.^{10,18,17} This difference could be explained on the basis of geographical, racial and study material difference. The depth of radius was more on right side and in predilection with authors in current study (Table 5).

Table 5: Comparison of anteroposterior (A-P), transverse diameter, circumference and depth of radial head with previous studies.

	Gupta et al ¹²	Singh and Singh ¹⁵	Ethiraj et al ¹⁴	Satyam and Radke ¹⁹	Reddy et al ¹⁷	Current Study
A-P diameter left (mm)	18.7±2.1	20.59±1.6	19.9±1.7	20.09±1.81	22.25±2.45	18.9±2
A-P Diameter right (mm)	19.6±1.8	20.44±2.45	20.3±2.2	20.32±1.92	22.44±2.23	19.03±1.74
Transverse diameter left (mm)	18.2±2.1	19.66±2.08	19.8±1.8	19.45±1.77	21.34±2.57	18.16±1.84
Transverse diameter right (mm)	18.9±2.1	19.43±2.39	19.8±2.4	19.85±1.86	21.56±2.21	18.44±1.86
Circumference left (cm)	-	-	-	-	7.13±0.86	6.7±0.7
Circumference right (cm)	-	-	-	-	7.16±0.80 cm	6.73±0.66
Depth left (mm)	1.9±0.51	1.9±0.37	2.93±0.53	-	2.35±0.51	1.97±0.56
Depth right (mm)	2±0.6	2.01±0.50	2.87±0.47	-	2.29±0.45	2.1±0.56

It is to be noted that though there was no significant correlation among the head parameters of both sides of radii but it is worth mentioning that two radii, one from each side, had thinned out radial heads. Radial head is a basic element of the physiological or prosthatic stability of both elbow joint as well as superior radio ulnar joint.^{20,21} Knowing the exact morphometry of radial head will allow orthopaedic surgeons for reconstructive surgeries pertaining to proximal end of radius and also help the biomedical engineers to manufacture the radial head prosthesis with more precision. In addition to this difference in radial head size is used in anthropology to determine the sex: with a maximum diameter of 23 mm and minimum diameter of 22 mm the subject is supposed to be male, and with maximum diameter of 22 mm and minimum diameter of 21 mm in female.²²

CONCLUSION

Current study advocates the importance of alignment of the morphology and morphometry of the radius head while treating several conditions related to it. It is needed that orthopedic surgeons follow protocols based on Indian population rather the western figures. Therefore, the data from the current study may be helpful in providing treatment protocol for orthopedic surgeons.

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