Original Article

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Anatomy Section

A Morphometric Study of Head of Radius and its Clinical Implication in Radial Head Prosthesis

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ABSTRACT

Introduction: The head of radius is a 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 the radial head circumference in pronation-supination.

Aim: The aim of the present study was to add some data on morphometry of radial head dimensions on dry human radial bones and to measure the various dimensions of the head of the radial bones.

Materials and Methods: A cross-sectional morphometric study was performed on 106 undamaged adult dry human radial bones of unknown age and gender by using a digital Vernier caliper of accuracy of 0.01 mm. Anteroposterior Diameter (APD), Transverse Diameter (TD), Medial Height (MH) and Lateral Height (LH) of radial head, Thickness of Ventral Curve (TVC), Lateral Curve (TLC), Dorsal Curve (TDC) and Depth of Superior Articular Facet (DH) were measured. Surface Area (SA) And Volume (V) of articular surface of head of radius by using mathematical calculations of a dome (the hemispherical concavity of the radial head) were also measured. The statistical analysis was done by using the SPSS software version 22.0. The Pearson's correlation test was used. Right and left side values were also correlated.

Results: In the present study mean values±standard deviation were 20.50±2.32 mm (APD), 19.52±2.26 mm (TD), 8.65±1.55 mm (MH), 6.26±1.09 mm (LH), 5.07±0.97 mm (TVC), 3.63±0.82 mm (TLC), 4.02±0.94 mm (TDC), 1.97±0.45 mm (DH), 331.37±73.82 mm^2 (SA) and 322.49±122.74 mm^3 (V).

Conclusion: The knowledge of size and shape of radial head is necessary for creation of radial head prosthesis that should be anatomically and biomechanically correct so that the open reduction and internal fixation and osteo-synthesis may be safely applied. Data may help orthopaedic surgeons for reconstructive surgeries.

Keywords: Elbow, Fovea radialis, Superior radio-ulnar joint

INTRODUCTION

Radius is lateral bone of forearm, has proximal and distal ends and a shaft. Proximal end includes head, neck and tuberosity. The head is discoid in shape, its superior articular shallow surface articulates with the capitulum of humerus. The articular circumference of head of radius articulates with the radial notch present in ulna and annular ligament. Articular surface and circumference of head of radius is covered with hyaline cartilage. Humero-radial joint permits flexion and extension movements at elbow joint and superior radioulnar joint permits supination and pronation movements of forearm. That's why proximal end of radius is very important clinically [1].

Fractures of proximal end of radius are approximately 1.7%-5.4% of all the fractures [2] and about 1/5th of all the fractures at elbow i.e. about 20% [3]. Treatment of radial head fractures are immobilization, excision with or without prosthetic replacement, open reduction and internal fixation. Sometime due to valgus forced injury to elbow, fracture of proximal end of radius complicate with the fracture of olecranon of the ulna. Prosthetic replacement of radial head has been suggested after excision of comminuted fracture of radial head [4]. Radial head prostheses were first proposed by Speed in 1941. He used a ferrule cup over the neck of radius [5]. Since than the use of acrylic, silicon rubber, vitallium and other metallic radial head prostheses has been there [6-8]. If orthropaedicians are performing hemiarthroplasty, the main goal is restoring the normal anatomy as much as possible. Radial head prostheses must restore maximum function of radial head within the elbow joint along with the correct positioning, load bearing and stability. Gupta GG et al., reported that currently available prosthetic implants are not anatomically correct and their designs are not derived from geometric dimensions of radial head [9]. Beredjiklian PD et al., measured various parameters of radial head by using magnetic resonant techniques and stated that currently available radial head prosthetic stem designs over estimated the intramedullary dimensions of radial head [10].

There are very few morphometric studies of radial head. So, the aim of the present study was to add some data on morphometry of radial head dimensions on dry human radial bones.

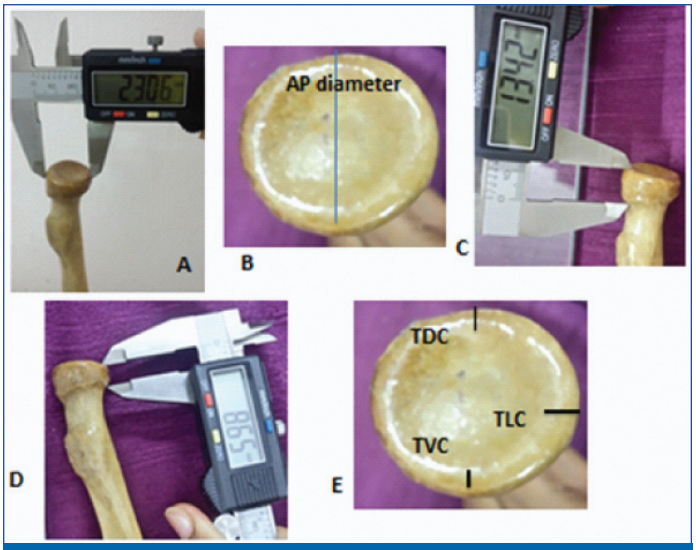
MATERIALS AND METHODS

A cross sectional study was conducted for three months from January 2018 to March 2018. Study was conducted according to the norms of the Institutional Ethical Committee (IEC) for cadaveric human dry bones. Sample size was taken conveniently and all the bones fulfilling the inclusion criteria were taken for measurements. Inclusion criteria was all the dry adult human radii available in the museum and exclusion criteria was damaged upper end, incomplete ossification, previous fracture or deformity. Present study was done on 106 complete and undamaged adult dry human radial bones of unknown age and gender, obtained from the department of Anatomy and Forensic medicine of Rohilkhand Medical College and Hospital, Bareilly (UP). Anatomical measurements were performed on these specimens using a digital Vernier caliper of accuracy of 0.01 mm. Following measurements were taken for head of radius, as carried out by other various studies [Table/Fig-1] [4,11].

Anteroposterior Diameter of radial head (APD): distance from most anterior point on the radial head to most posterior point.

Transverse Diameter of radial head (TD): distance from medial point on radial head to most lateral point.

Medial Height of radial head (MH): distance between radial lip and head and neck junction on medial side. (Height of circumference of radial head at medial side).

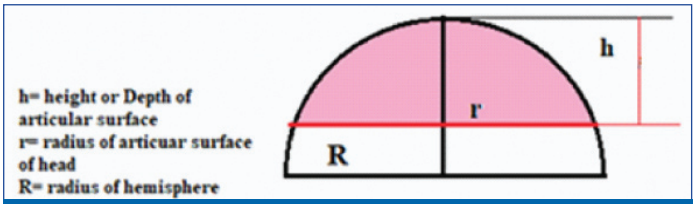


[Table/Fig-1]: Measurements of head of radius. A) Transverse diameter of head of radius; B) Anteroposterior diameter of head of radius; C) Medial height of head of radius; D) Lateral height of head of radius; E) TVC, TLC and TDC- curve thickness of superior articular surface.

Lateral Height of radial head (LH): distance between the radial lip and head & neck junction on lateral side. (Height of circumference of radial head at lateral side) Thickness of Ventral Curve (TVC), Thickness of Lateral Curve (TLC) and Thickness of Dorsal Curve (TDC): thickness of curve on superior articular surface of head on ventral, lateral and dorsal aspects respectively.

Depth of Superior Articular Facet (DH): scale put over the radial head touching most prominent anterior and posterior rim of radial head and depth in centre was measured by digital Vernier caliper.

Surface Area (SA) and Volume (V): of articular surface of head of radius: The surface area and volume were challenging to be measured at such small-scale. Method of measurement was used, mathematical calculations of a dome (the hemispherical concavity of the radial head) [Table/Fig-2].



[Table/Fig-2]: Measurements related to surface area and volume of superior articular surface of radius.
SA = Surface Area of superior articular surface of head of radius, ϖ = 3.14159, h = height or depth of articular surface, r = radius of articular surface of head, v = volume of superior articular surface of head of radius

Formulas [12]:

$$SA = \pi(h^2 + r^2)$$

$$v = \frac{1}{6}\pi\, h(3r^2 + h^2)$$

Each parameter was measured by the principal investigator and rechecked by the second investigator to avoid human error. Recorded data were tabulated and analysis was done by IBM SPSS Statistics Version 22.0 software. Pearson's correlation test was used. Right and left side values were also correlated. The p-values less than 0.05 were taken significant.

RESULTS

In present study mean values±standard deviation were 20.50±2.32 mm (APD), 19.52±2.26 mm (TD), 8.65±1.55 mm (MH), 6.26±1.09 mm (LH), 5.07±0.97 mm (TVC), 3.63±0.82 mm (TLC), 4.02±0.94 mm (TDC), 1.97±0.45 mm (DH), 331.37±73.82 mm^2 (SA) and 322.49±122.74 mm^3 (V) [Table/Fig-3].

N=106	Mean±SD	Minimum	Maximum
APD (mm)	20.50±2.33	15.96	26.19
TD (mm)	19.53±2.26	15.22	25.02
MH (mm)	8.65±1.55	5.48	13
LH (mm)	6.28±1.09	3.90	9.44
TVC (mm)	5.07±0.96	2.89	7.32
TLC (mm)	3.63±0.82	1.54	5.04
TDC (mm)	4.02±0.94	2.06	5.98
DH (mm)	1.96±0.44	1.12	3.61
SA (mm^2)	331.37±73.82	200.32	539.35
VOL (mm^3)	322.49±122.74	116.16	732.10

[Table/Fig-3]: Morphometric values of total radius irrespective of side of radius.
APD: Anteroposterior Diameter; TD: Transverse Diameter; MH : Medial Height; LH: Lateral Height; TVC: Thickness of Ventral Curve; TLC: Thickness of Lateral Curve; TDC:Thickness of Dorsal Curve; DH: Depth of Superior Articular Facet; SA: Surface Area; VOL: Volume

Mean±SD, minimum and maximum values of morphometric parameters of right (n=62) and left side (n=44) of radius are given in [Table/Fig-4,5]. Comparison was done between the values of right and left side and t-value, p-value were shown in [Table/Fig-6]. A significant difference was present between the values of medial height (p=0.001), thickness of ventral curve (p=0.009) and thickness of dorsal curve (p=0.001) of right and left side of radius, where the p=<0.05.

Parameters N=62	Mean (mm)	Minimum (mm)	Maximum (mm)	Std deviation
APD	20.44	15.96	26.19	2.45
TD	19.43	15.22	25.02	2.39
MH	7.99	5.48	10.69	1.39
LH	6.40	3.97	9.44	1.17
TVC	4.84	2.89	7.32	1.05
TLC	3.49	1.54	5.01	0.90
TDC	3.74	2.06	5.77	0.99
DH	2.01	1.42	3.61	0.50
SA	330.16	200.32	539.35	77.80
V	326.90	165.62	732.10	131.34

[Table/Fig-4]: Various parameters of right radial head.
APD: Anteroposterior Diameter; TD: Transverse Diameter; MH : Medial Height; LH: Lateral Height; TVC: Thickness of Ventral Curve; TLC: Thickness of Lateral Curve; TDC:Thickness of Dorsal Curve; DH: Depth of Superior Articular Facet; SA: Surface Area; V: Volume

Parameters N=44	Mean (mm)	Minimum (mm)	Maximum (mm)	Std deviation
APD	20.59	16.76	25.18	2.16
TD	19.66	15.64	23.27	2.08
MH	9.57	7.70	13.00	1.40
LH	6.10	3.90	7.55	0.95
TVC	5.41	3.75	6.84	0.73
TLC	3.83	2.93	5.04	0.65
TDC	4.43	3.22	5.98	0.70
DH	1.9	1.12	2.71	0.37
SA	333.09	210.06	483.80	68.67
V	316.30	116.16	634.70	110.68

[Table/Fig-5]: Various parameters of left radial head.
APD: Anteroposterior Diameter; TD: Transverse Diameter; MH : Medial Height; LH: Lateral Height; TVC: Thickness of Ventral Curve; TLC: Thickness of Lateral Curve; TDC:Thickness of Dorsal Curve; DH: Depth of Superior Articular Facet; SA: Surface Area; V: Volume

Statistical analyses using Pearson's correlation test, proved an existing correlation between depth vs. surface area, depth vs. volume and area vs. volume. In all of correlations, the p-values were found to be less than 0.00001, which is a very strong positive (+ve) linear correlation for these tested parameters [Table/Fig-7].

Parameters	Right Side (N=62) Mean±SD	Left side (N=44) Mean±SD	t-value	p-value
APD	20.44±2.45	20.59±2.16	0.38	0.709
TD	19.43±2.39	19.66±2.08	0.41	0.685
MH	7.99±1.39	9.57±1.40	5.59	<0.001
LH	6.40±1.17	6.10±0.95	1.85	0.071
TVC	4.84±1.05	5.41±0.73	2.75	0.009
TLC	3.49±0.90	3.83±0.65	1.14	0.259
TDC	3.74±0.99	4.43±0.70	3.52	0.001
DH	2.01±0.50	1.9±0.37	1.25	0.217
SA	330.16±77.80	333.09±68.67	0.18	0.862
V	326.90±131.34	316.30±110.68	0.40	0.690

[Table/Fig-6]: Comparisons of morphometric values of right and left radial Head. APD: Anteroposterior Diameter; TD: Transverse Diameter; MH : Medial Height; LH: Lateral Height; TVC: Thickness of Ventral Curve; TLC: Thickness of Lateral Curve; TDC:Thickness of Dorsal Curve; DH: Depth of Superior Articular Facet; SA: Surface Area; V: Volume

Correlates	Pearson's r-value	p-value	Significance
Depth vs Surface Area	0.394	<0.001	yes
Depth vs Volume	0.804	<0.001	yes
Surface Area vs Volume	0.844	<0.001	yes

[Table/Fig-7]: Correlation between depth, surface area and volume of radial head and Pearson's values.

DISCUSSION

The head of radius is a fundamental element for the physiological [13] or prosthetic [14-16] stability of the elbow and superior radioulnar joint. The total articular circumference does not articulate with the radial notch in the pronation-supination motion. There is a non-articulating portion, which covers 1130 on average, and is located in the dorsal and slightly lateral portion of the radial circumference [17]. The height of the articular circumference is the same in the ventral and dorsal portions while that of the medial portion is greater and represents nearly all the height of the radial head. This height is very important from the biomechanical point of view, and must be conserved to avoid articular complications in both elbow and wrist [18]. An upward displacement of the radius occurs when medial height of circumference of head of radius decreases and it results in progressive laxity of the radioulnar ligaments and the interosseous membrane, which increases the instability [19].

Puchwein P et al., found the mean AP diameter of the radial head at its widest part as 2.3 cm, in the transverse plane as 2.24 cm and Captier G et al., reported 2.16 cm at its widest part (AP diameter) and in the transverse plane as 2.1 cm [20,21]. While values reported by various Indian authors [4,22,23] was less than values reported by king GJ et al., Puchwein P et al., and Captier G et al., [Table/Fig-8] [15,20,21].

Medial height and lateral height of circumference of radial head was reported by Puchwein P et al., 11.7 mm and 11.8 mm respectively [20]; which was higher than values of Gupta C et al., (reported 9 mm and 7.5 mm respectively) [22]; Shastry A et al., (reported 9.79 mm and 7.73 mm respectively) [4]; and the present study (reported 8.65 mm and 6.28 mm). This may be because Puchwein P et al., measured values by CT Scan while all other authors measured dry bone [20].

Captier G et al., reported thickness of curve present on superior articular surface, TVC, TLC and TDC was 5.5 mm, 4.7 mm and 4.3 mm respectively (TVC>TLC>TDC) [21]; Gupta C et al., reported 4.2 mm, 3 mm and 3.2 mm respectively (TVC>TDC>TLC) [22]; Shastry A et al., measured 5.05 mm, 3.64 mm and 3.69 mm respectively (TVC>TDC>TLC) [4]; Mittal A et al reported 5.4 mm, 4.3 mm and 4.1 mm respectively (TVC>TLC>TDC) [23] and present study reported 5.07mm, 3.63 mm and 4.02 mm respectively (TVC>TDC>TLC).

Depth of superior articular surface reported by present study was 1.96 mm which was similar to Al-Imam A et al., (1.983 mm) and Gupta C et al., 1.9 mm [11,22], while values recorded by Shastry A et al., was less (1.735 mm) [4]. Al-Imam A et al., recorded surface area and volume of superior articular surface of head of radius was 320.6 mm^2 and 318 mm^3 [11] which was almost similar with the values of present study which was 331.37 mm^2 and 322 mm^3 respectively. There was strong correlation present between depth vs surface area, depth vs volume and surface area vs volume in the present study which was also reported by Al-Imam A et al., [11].

LIMITATION

Smaller sample size, unknown geographical area of origin of bones, no supplementation by imaging techniques are some of the limitations of the present study. Further studies can be done with larger sample size and known geographical area of origin of bones.

CONCLUSION

The statistical correlations of this study based on Pearson's correlations test show strong correlations between three of the measured parameters: depth and surface areas, depth and volume and surface area and volume. Data may help orthopaedic surgeons for reconstructive surgeries and will also provide a precision leverage and validity for the biomedical engineering to manufacture explicit radial head prostheses.

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