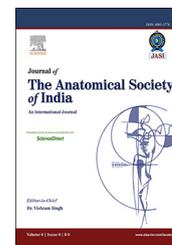


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Original Article

Morphometric study of proximal ulna with special emphasis on angulations



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ABSTRACT

Introduction: The proximal ulna shows angulations in the coronal plane and in the sagittal plane. The angulation in the coronal plane is named as varus angulation. The proximal ulna also deviates anteriorly to the long axis of shaft of ulna making an anterior angle (proximal dorsal angle of ulna). The angle between the posterior and superior surface of olecranon is olecranon angle.

The aim of the present study is to provide complete osteometric data of proximal ulnar angulations and dimensions in North-Indian population.

Methods: Present study was conducted on 50 right and 50 left side dried ulna bones without any deformity. Angles were measured with goniometer and other linear parameters were taken with vernier calipers.

Results: The total mean length of ulna was recorded as 26.11 ± 1.69 cm. The mean varus angle was observed as $10.78 \pm 2.51^\circ$ in total samples. The average anterior angle appeared as $8.06 \pm 2.72^\circ$ which range between 2.0° and 14.0° . The olecranon angle range was found between 94.0° and 118.0° with mean value of $103 \pm 5.2^\circ$. The mean distance from MPPDS point to PMVA and PAA was recorded as 7.87 ± 0.72 cm and 9.07 ± 1.03 cm respectively. Mid-shaft thickness was observed as 1.32 ± 0.23 cm.

Discussion: Considerable variations were found in the parameters measured for the proximal ulna so this is concluded that the data collected in the present study would be of importance in catering the ulnar plates according to the angles and dimensions of ulna found in North-Indian population.

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1. Introduction

Ulna is the medial bone of forearm plays a significant role in formation of proximally elbow joint, distally wrist joint and being a weight bearing bone its anatomical geometry is of great

concern, proximally the ulna has a bony process, the olecranon process, a hook-like structure that fits into the olecranon fossa of the humerus in extension. This prevents hyperextension and forms a hinge joint with the trochlea of the humerus. Its posterior surface is smooth, triangular and subcutaneous, with its proximal border underlies the 'point' of

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the elbow. Its anterior articular surface forms the proximal area of the trochlear notch. Its base is slightly constricted where it joins the shaft and is the narrowest part of the proximal ulna. The coronoid process projects anteriorly distal to the olecranon. Its proximal aspect forms the distal part of the trochlear notch. The proximal ulna shows angulations in the coronal plane and in the sagittal plane. The angulation in the coronal plane is named as varus angulation because the olecranon process is slightly deviated towards lateral side thus the long axis of the shaft makes an approximately 5–9° angle. Not only laterally the proximal ulna also deviates anteriorly to the long axis of shaft of ulna making an anterior angle (proximal dorsal angle of ulna). The posterior border of olecranon superiorly shows a sharp band to be present as the superior surface of olecranon process. The angle between the posterior and superior surface of olecranon is called as olecranon angle.

Very fewer studies have been conducted on the proximal ulnar morphometry. Injuries of the proximal ulna make it necessary about in depth knowledge of proximal ulnar morphometry for its surgical correction and management.

Fractures of proximal ulna are more complex and anatomical reduction is necessary both in Monteggia-type fractures and intra-articular olecranon fractures. Restoration of articular congruity and orientation may allow early mobilization and prevent radial head sub-luxation, early arthritis and loss of function.¹⁻³

Ulna bone shows complex shape of olecranon process but, for a long period of time, surgeons used to apply non-anatomical plates with no significant difficulties.^{4,5} Recently it is practiced that these plates reshaped during operation to fit to bone geometry. Bending plates have never been easy especially parallel to the posterior and superior surfaces of olecranon process. Then there comes the use of anatomical pre-shaped olecranon plates keeping in view of the average angulations of the ulna, which eliminate the hassle of intra-operative bending and also reduces the time period of surgical procedure. As far as the pre-shaped olecranon plates used that must correspond to the average geometry of the proximal ulna and this has been noted that ulnar morphometric parameters vary according to age and race.

Our aim of the present study is to provide complete osteometric data of proximal ulnar angulations and dimensions in North-Indian population and to compare the results with those reported in previous studies.

2. Material and methods

The Present study was conducted in the Department of Anatomy, S. P. Medical College, Bikaner. A total 100 dried ulna bones (50 right sides and 50 left sides) which belonged to unknown sex and age were collected and bones having evidence of fracture, postmortem damage or arthritis which could prevent accurate measurements were excluded from the study. Proximal ulna presents varus angulation in the coronal plane and anterior angulation in the sagittal plane. Both the angles were measured using a digital goniometer (graduated to 1°). Initially, the imaginary point of maximum varus angulation (PMVA) of ulna was observed and placed on its dorsal

surface. Then the four points were located on the dorsal surface of proximal ulna out of four points two points proximal to the imaginary PMVA point and two distal to that, among two proximal points one was marked at the tip of olecranon process and other at the mid distance from tip to the imaginary PMVA point. About the two distal points, one was taken at the mid point of length of ulna (mid point of bone) and the other at the mid distance between this mid point of bone and the imaginary PMVA point. At all these four points the transverse side to side diameter of the bone measured with the help of vernier calipers and the points were adjusted according to the middle of each transverse diameter taken. The two long axes of ulna were drawn, first passing through the proximal two points of imaginary PMVA and the second one passing through the distal two points of the imaginary PMVA, thus by drawing these two axes the intersecting point of the two axes was obtained and marked as the definitive PMVA point (See Image 1). Then varus angle of the ulna measured by keeping the two arms of goniometer parallel to the axes drawn at the definitive PMVA (See Image 2). The point of anterior angle was located by seeing the bone from its lateral aspect and finding the maximum dorsal curve of ulnar shaft which was marked as PAA (point of anterior angulation). The anterior angle was measured keeping the two arms of goniometry parallel to the

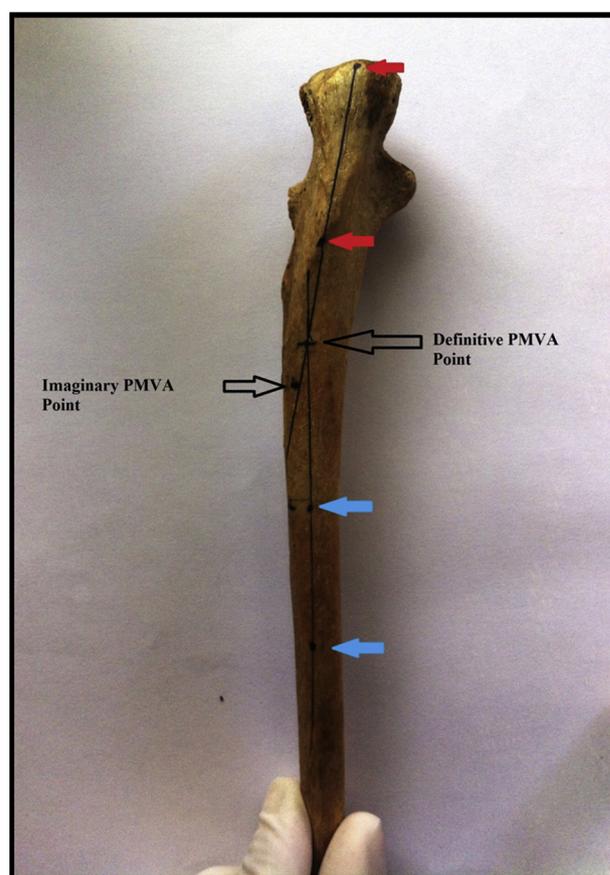


Image 1 – Two axes intersecting at the definitive PMVA (Point of maximum varus angulation) at the dorsal surface of ulna. Red arrow indicates the proximal two points to imaginary PMVA. Blue arrow indicates the distal two points to imaginary PMVA.

surfaces proximal and distal to the PAA (See Image 3). The most proximal point on dorsal surface of ulna was located and marked as MPPDS. The most anterior point of the superior rough surface of olecranon was termed as MAPSS.

A distance of MPPDS was measured from the PMVA and PAA points. On the dorsal surface of the shaft the midpoint of the bone was located half way of the total length of the ulna. The distances from the mid-point to the PMVA and PAA point were measured. The olecranon length was measured as the distance between MPPDS and MAPSS point. The olecranon angle was measured between dorsal and superior surfaces of olecranon process by keeping the one arm of goniometer parallel to the superior surface of olecranon and the other arm was placed parallel to the dorsal surface. The thickness of the bone was measured antero-posteriorly (in sagittal plane) right angle to the long axis of the bone at following three points;

1. At the trochlear notch level where the distance was minimum
2. At the ulnar tuberosity of coronoid process level
3. At the mid point of the bone level

One Another oblique distance was also measured from the MPPDS to lower border of radial notch on the lateral aspect of lateral surface of the upper end of the ulna. The above distances were measured, keeping in view of the screw placement in oblique direction during fixation of ulnar plate. All the distances were measured with the help of metallic vernier caliper in centimeters up to the level of 0.1 mm. Each



Image 2 – Measurements of varus angle at the definitive PMVA point with goniometer.

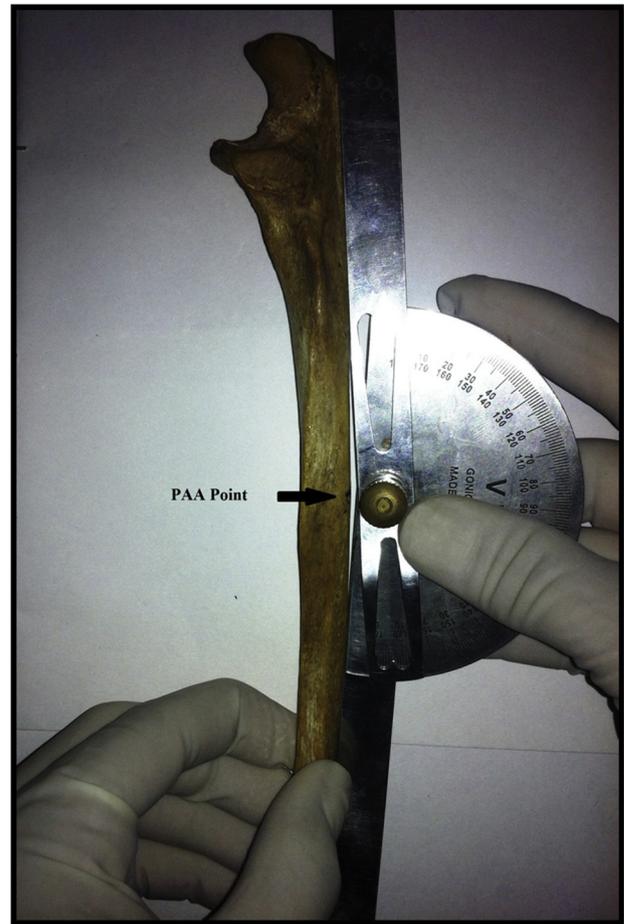


Image 3 – The measurement of anterior angle of ulna with the help of goniometer.

measurement was taken thrice and the mean of that was recorded for statistical analysis using SPSS 17.0 windows software. Mean, SD were calculated for all the parameters and tabulated.

3. Result

A total of 100 (50 right and 50 left) dry ulna bones were selected. Mean values of all the parameters are shown in Tables 1 and 2. The mean total length of the ulna was found as 26.10 ± 1.75 cm on right side and 26.12 ± 1.65 cm on left side. The total mean length of right and left pooled data was recorded as 26.11 ± 1.69 cm. The length of the ulna range between 22.6 cm and 30 cm for right side and 22 cm–30.2 cm for left side, the combined range of right and left side was found in between 22 cm lower to 30.2 cm higher.

The mean distance between PMVA and MPPDS points was found as 7.76 ± 0.65 cm on right side and 7.98 ± 0.77 cm on left side. Whereas the mean distance of right and left pooled data was found as 7.87 ± 0.72 cm.

The mean distance between PAA to MPPDS points was recorded as 8.89 ± 1.10 cm on right side and 9.26 ± 0.93 cm on left side. The mean distance of total data was found 9.07 ± 1.03 cm.

Table 1 – Descriptive statistics of proximal ulnar measurements.

Parameters		Mean	Std. deviation	Minimum	Maximum
Total length of ulna	Right	26.106	1.7576	22.6	30.0
	Left	26.122	1.6550	22.0	30.2
	Total	26.114	1.6984	22.0	30.2
Varus angle (°)	Right	11.6800	2.44482	6.00	18.00
	Left	9.8800	2.27578	5.00	15.00
	Total	10.7800	2.51794	5.00	18.00
Anterior angle (PUDA) (°)	Right	8.4400	2.27820	3.00	14.00
	Left	7.6800	3.08346	2.00	13.00
	Total	8.0600	2.72408	2.00	14.00
Olecranon angle (°)	Right	103.7800	5.69386	94.00	118.00
	Left	102.3200	4.61338	95.00	114.00
	Total	103.0500	5.20756	94.00	118.00
Distance of PAA from MPPDS point	Right	8.8902	1.10028	6.18	11.23
	Left	9.2634	0.93601	7.39	11.00
	Total	9.0768	1.03344	6.18	11.23
Olecranon length	Right	1.4010	0.27339	0.85	1.98
	Left	1.3692	0.21730	1.00	1.80
	Total	1.3851	0.24621	0.85	1.98
Distance of PMVA from MPPDS point	Right	7.7658	0.65952	6.41	9.13
	Left	7.9898	0.77654	6.67	9.66
	Total	7.8778	0.72555	6.41	9.66

All the angles are in degrees and linear parameters are in centimeters.

The olecranon mean length was recorded 1.40 ± 0.27 cm on right side and 1.36 ± 0.21 cm on left side. The total mean value of olecranon length was found as 1.38 ± 0.24 cm.

The mean distance from MPB (Mid point of bone) to PMVA point was found more on right side 5.05 ± 0.54 cm and less for left side 4.76 ± 0.83 cm. In total samples the mean distance came out as 4.90 ± 0.71 cm. Similarly the distance measured from MPB to PAA point shows a mean value of 3.87 ± 0.99 cm and 3.50 ± 0.91 cm for right and left side respectively and 3.68 ± 0.96 cm in total number of sample.

Anterio-posterior olecranon thickness at trochlear notch level was observed as 1.76 ± 0.32 cm and 1.72 ± 0.32 cm for right and left side respectively and 1.74 ± 0.32 cm in total

number of sample. Anterio-posterior olecranon thickness at coronoid process shows a mean value of 1.89 ± 0.29 cm and 1.87 ± 0.25 cm for right and left side respectively and 1.88 ± 0.27 cm in total number of sample. Anterio-posterior thickness at mid point of bone was observed as 1.23 ± 0.18 cm and 1.40 ± 0.25 cm for right and left side respectively and in total it was 1.32 ± 0.23 cm. Olecranon process oblique distance was observed as 3.86 ± 0.37 cm and 3.83 ± 0.33 cm for right and left side respectively and in total sample it was found as 3.84 ± 0.35 cm.

In the present study the mean varus angle was observed slightly more for right side ($11.68 \pm 2.44^\circ$ and $9.88 \pm 2.27^\circ$ for right and left side respectively) and $10.78 \pm 2.51^\circ$ in total

Table 2 – Descriptive statistics of proximal ulnar measurements.

Parameters		Mean	Std. deviation	Minimum	Maximum
Distance of PAA from MPB	Right	3.8770	0.99189	1.93	7.42
	Left	3.5008	0.91031	2.02	5.79
	Total	3.6889	0.96584	1.93	7.42
Distance of PMVA from MPB	Right	5.0518	0.54540	4.12	6.27
	Left	4.7646	0.83254	3.20	7.20
	Total	4.9082	0.71492	3.20	7.20
Olecranon thickness at trochlear level	Right	1.7698	0.32669	1.22	2.96
	Left	1.7260	0.32594	1.13	3.41
	Total	1.7479	0.32541	1.13	3.41
Coronoid thickness	Right	1.8926	0.29817	1.17	2.56
	Left	1.8710	0.25413	1.42	2.54
	Total	1.8818	0.27584	1.17	2.56
Olecranon oblique distance	Right	3.8684	0.37906	3.14	4.55
	Left	3.8308	0.33422	3.33	4.94
	Total	3.8496	0.35604	3.14	4.94
Mid point of bone (MPB) thickness	Right	1.2398	0.18530	0.91	1.65
	Left	1.4010	0.25800	0.84	1.90
	Total	1.3204	0.23770	0.84	1.90

All the parameters are in centimeters.
MPB – Mid point of bone.

samples. The mean value for anterior angle was measured slightly less than varus angle. Anterior angle was recorded $8.44 \pm 2.27^\circ$ for right side which is higher than the mean anterior angle of left side $7.68 \pm 3.08^\circ$. In total number of sample the average anterior angle appeared as $8.06 \pm 2.72^\circ$. The anterior angle of the ulna is quite variable and range between 2.0° and 14.0° in all the samples. The olecranon angle range between 94.0° and 118.0° in total number of sample, the mean olecranon angle was $103 \pm 5.2^\circ$. The mean olecranon angle is equal in both sides.

4. Discussion

Of the 100 ulna bones studied, in which 50 right and 50 left with the mean length observed as 26.11 cm. All the samples showed a considerable radial deviation in the olecranon process. All the ulna bones showed anterior deviations at the mean distance of 9.07 cm (PAA) from the most proximal point of the ulnar shaft however the varus angle was at a mean distance of 7.87 cm, which is proximal to the point of anterior angle. The mean length of ulna is similar to the mean length reported in a study by A Fuat et al.⁶

In the present study the mean varus angle was found as 10.78° , similar finding has been reported by Young WJ et al on CT study of a number of 20 cadavers.⁷ Some other previous studies report a higher varus angle as in case of Puchwein P et al (14.3°) and 17.7° was reported by Windisch G et al.^{8,9} Grccheing W et al¹ also supports the findings of Windisch G et al with the mean varus angle was 17.5° on 54 cadaveric sample.

Anterior angle of the proximal ulna was found as 8.06° which is higher than the other previous studies; according to Young WJ et al⁷ mean anterior angle was 4.3° which is very less as compare to present study. In this series only the finding of the Puchwein P⁸ et al (6.2°) is close to the mean value of the present study.

In this present study the olecranon angle was observed as 103.05° and this is being reported in one previous study by Puchwein P⁸ as 95.3° , there is a similarity of olecranon angle between the above mention two studies. Another previous study¹⁰ reports the mean olecranon angle as 110.3° . The mean distance of varus angle point (PMVA) from MPPDS was found as 7.87 cm which is close to the findings of T Totlis¹⁰ (8.19 cm), very close mean distance has also been observed by Windisch G et al⁹ (8.54 cm).

The distance between PAA and MPPDS was found as 9.07 cm which is slightly higher than the findings of T Totlis¹⁰ (8.63 cm), a very less mean distance between PAA and MPPDS (4.7 cm) has also been reported by Rouleau DM et al.^{3,11}

The mean olecranon length was observed as 1.38 cm in the present study which is slightly less as compare to the reported by T Totlis¹⁰ (1.58 cm), an attempt also has been made to measure the distances of PAA and PMVA points to the mid point of bone. The distance of PAA to mid point of bone was found 3.68 cm, which would be useful in deciding the length of the part of ulnar plate which is parallel to the ulnar shaft. Antero-posterior thicknesses of proximal ulna were measured keeping in view of the length of screws used in fixation of ulnar plates while managing proximal ulnar fractures. The

olecranon tip thickness was reported by Young WJ et al⁷ to be 1.78 cm and they have also reported the thickness at two other places namely at level of trochlea 1.97 cm and at the level of coronoid process 3.51 cm, in the present study we have found the mean values for the same points as 1.74 cm and 1.88 cm respectively, these values are less may be due to variation in the deciding the point of measurement.

The review of literature suggest that there are considerable variations in the parameters measured for the proximal ulna specially the angulations. The varus angle range from 5° to 18° and the anterior angle range from 2° to 14° . The present study is one of the few studies conducted on Indian samples, author believe that the data collected in the present study would be of importance in catering the ulnar plates according to the angles and dimensions of ulna found in North-Indian population.

5. Conclusion

Considerable variation in the parameters measured for the proximal ulna especially the angulations have been reported previously. The varus angle range from 5° to 18° and the anterior angle range from 2° to 14° thus make it necessary to conduct more studies on large number of samples in different geographical areas. The present study is one of the few studies conducted on Indian samples, author believe that the data collected in the present study would be of importance in catering the ulnar plates according to the angles and dimensions of ulna found in North-Indian population.

Conflicts of interest

There is no conflict of interest between all the authors.

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