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Do the Proximal Ulnar Angulations Have Correlations with Each Other? Anatomical Study and Review of the Literature

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ABSTRACT

Objective: The proximal ulna has a complex and unique architectural anatomy, therefore, its fractures are difficult to manage. This paper aimed to evaluate proximal ulnar angulations that contribute to the fixation and restoration of proximal ulna fractures in the Turkish population.

Materials and Methods: This study was performed on 107 Turkish adult ulnae (55 right, 52 left) whose age and sex were unknown. The ulnar length (UL), proximal distance of varus angulation (PDVA), and widths at the point of varus angulation were measured with a digital caliper. The proximal ulna torsion angle (PUTA), varus angulation (VA), proximal ulna dorsal angulation (PUDA), articular angle (AA), and olecranon–diaphysis angle (ODA) were measured with a goniometer. The statistical analysis was carried out at the SPSS 21.0 program (IBM Corporation, Armonk, NY, USA).

Results: The median UL was 251.97 mm (minimum: 196.84 – maximum: 497.76 mm), median PDVA was 82.7 mm (minimum: 16.21 – maximum: 108.62 mm), mean total width was 15.04±1.84 mm, mean posterior-interosseous width was 13.72±2.37 mm and mean posterior-anterior width was 15.15±1.93 mm. The mean PUTA was 27.10°±9.04°, the median VA was 14° (minimum: 5° – maximum: 23°), the median PUDA was 8° (minimum: -3° – maximum: 20°), the median AA was 25° (minimum: 19° – maximum: 39°), and the mean ODA was 17.39°±5.33°. A moderate negative correlation was detected between the PUDA and ODA (rs= -0.50, p<0.001).

Conclusion: The mean proximal ulnar angulations in this study can be beneficial during surgery for the fixation of proximal ulna fractures. This study revealed the correlation between proximal ulnar angulations in the Turkish population.

Keywords: Ulna, proximal ulna fractures, proximal ulnar angulations, Monteggia fractures.

INTRODUCTION

Proximal ulna fractures range from simple transverse olecranon fractures to highly complex Monteggia fractures.[1] The overall prevalence of these fractures is 1.1% and constitutes approximately 21% of all proximal forearm fractures.[1] Proximal ulna fractures are common injuries at any age; however, they increase in adults in the seventh decade of life and peak in the ninth decade.[2] Currently, the treatment options for proximal ulna fractures include tension band fixation, K-wire/screw tension band fixation, intramedullary nail fixation, and plate fixation.[3,4] The fundamental goal of surgical treatment is to obtain normal anatomical restoration of the ulna without an unrestricted elbow joint.[4] Proximal ulnar angulations such as the varus angle (VA), proximal ulna dorsal angulation (PUDA), and olecranon-diaphysis angle (ODA) should be taken in mind in the restoration of proximal ulna fractures.[5] An inaccurate restoration of these angulations and opposing the normal elbow anatomy may lead to such as the restricted elbow joints, elbow instability, and osteoarthritis.[6–8] In this context, the goal of this anatomical study was to focus on the proximal ulnar angulations, which are important for the restoration of proximal ulna fractures, and to reveal the relationships between these angles with each other and with some other parameters.

MATERIALS AND METHODS

For this cross-sectional study, a total of 107 Turkish adult dry ulnae sample (55 right, 52 left) that had no records of their age and sex and that were received from the Department of Anatomy, İstanbul Faculty of Medicine İstanbul University were used. The inclusion criteria were as follows. Ulnas that belonged to adults (only bones that belonged to adults are found in our department) and the absence of any gross pathology and/or deformity that could affect the measurements made on the bones. Exclusion criteria were the presence of any gross pathology and/or deformity that could affect the measurements made on the bones and ulnas that belonged to children/babies.

To diminish potential bias, all measurements were conducted by two independent researchers, and the average of the two values per parameter was recorded. If the measurement difference between researchers was more than 10%, both measurements were repeated. The ulnar angulations were determined with a goniometer (Yıldızlar goniometer, Türkiye), and a digital caliper that was accurate to 0.01 mm (INSIZE Co., Ltd., Taiwan) was used for distances. Ethical approval of this paper was granted by the Clinical Research Ethical Committee of Istanbul University, İstanbul Faculty of Medicine (Date: 25/06/2021, Number: 13).

The following measurements were performed on each ulna:

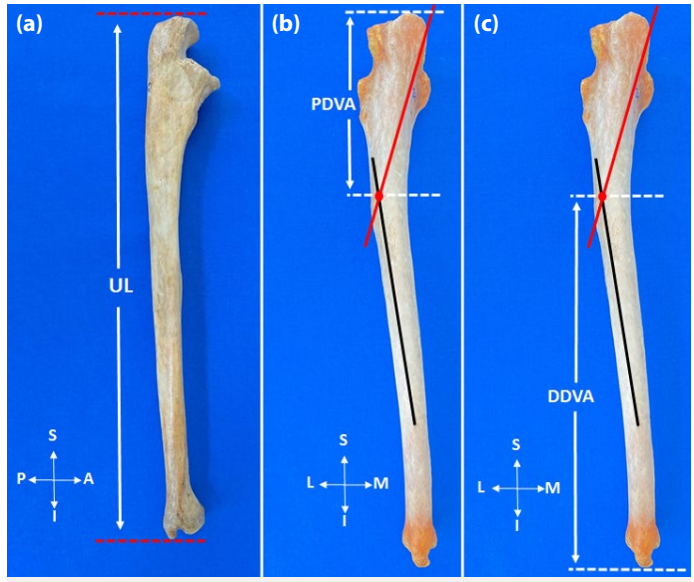

Figure 1. The ulnar length (UL) **(a)**, the proximal distance of varus angulation (PDVA) **(b)**, the distal distance of varus angulation (DDVA) **(c)**, anterior (A), posterior (P), medial (M), lateral (L), superior (S), inferior (I) left ulna, the red round dot marks the point where the posterior border is angled.

Distances

- The ulnar length (UL) was measured as the vertical distance between the most prominent point of the olecranon, proximally, and the tip of the styloid process, distally (Fig. 1a).
- The proximal distance of varus angulation (PDVA) was defined as the vertical distance between the most prominent point of the olecranon and the varus angulation point (Fig. 1b).
- The distal distance of varus angulation (DDVA) was obtained as the vertical distance between the varus angulation point and the tip of the styloid process (Fig. 1c).
- The width at the point of varus angulation (WPVA) was determined as the transverse width at the point of angulation of the posterior border (Fig. 2a).
- The distance between the anterior and posterior borders (DAPB) was defined as the shortest distance between the posterior border and the anterior border at the point where the posterior border was angled (Fig. 2b).
- The distance between the posterior and interosseous borders (DPIB) was defined as the shortest distance between the posterior border and the interosseous border at the point where the posterior border was angled (Fig. 2c).

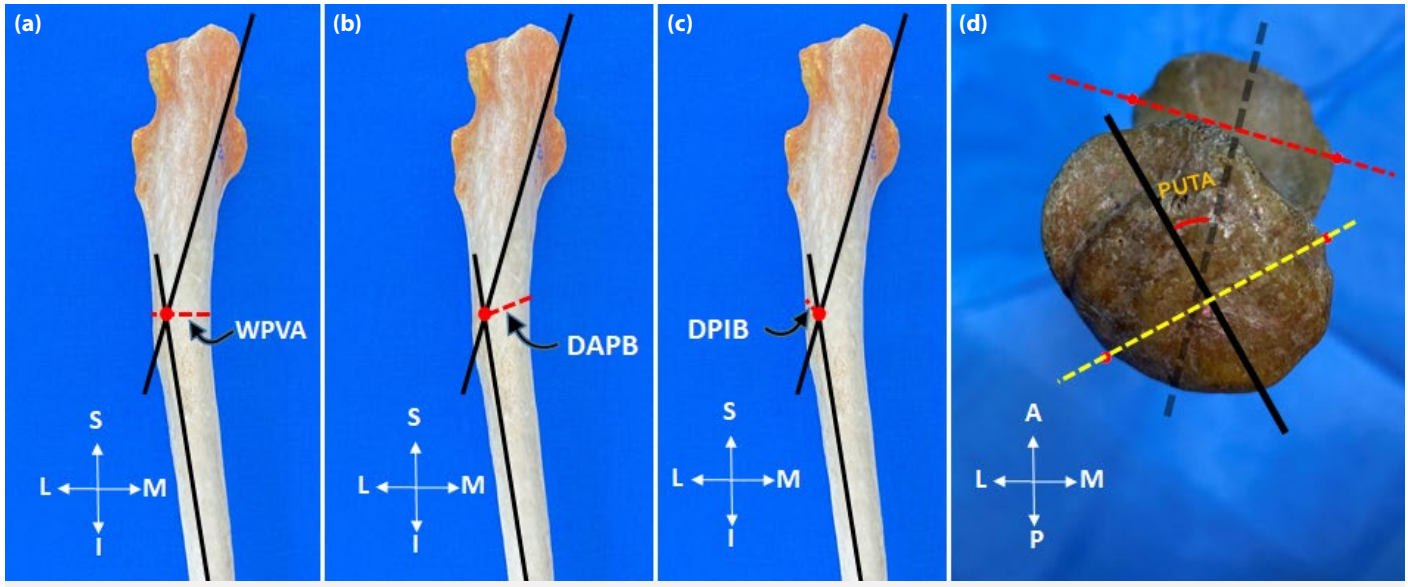

Figure 2. The width at the point of varus angulation (WPVA) **(a)**, the distance between the anterior and posterior border (DAPB) **(b)**, the distance between the posterior and interosseous border (DPIB) **(c)**, the proximal ulna torsion angle (PUTA) **(d)**, the yellow dashed line connecting the most protruding points medial and lateral of the olecranon, the red dashed line connecting the most protruding points medial and lateral of the trochlear notch, the black line refers to the axis that passes perpendicularly through the middle of the yellow dashed line, black dashed line the axis that passes perpendicularly through the middle of the red dashed line, anterior (A), posterior (P), medial (M), lateral (L), superior (S), inferior (I) left ulna, the red round dot marks the point where the posterior border is angling.

Angulations

- The proximal ulna torsion angle (PUTA) was identified as the angle between the axes that pass perpendicularly through the middle of the lines connecting the most prominent points medial and lateral to the olecranon and trochlear notch (Fig. 2d).
- The varus angulation (VA) was defined as the acute angle where the posterior border was angled (Fig. 3a).
- The proximal ulna dorsal angulation (PUDA) was measured as the angle between the long axis of the shaft of the ulna and the longitudinal axis passing posterior to the olecranon (Fig. 3b).
- The articular angle (AA) was measured as the angle between the longitudinal axis passing posterior to the olecranon and the axis passing through the most protruding point of the upper and lower end of the trochlear notch (Fig. 3c).
- The olecranon–diaphysis angle (ODA) was defined as the angle between the long axis of the body of the ulna and the axis passing through the most protruding point of the upper and lower end of the trochlear notch (Fig. 3d).

Statistical analysis

The Shapiro-Wilk Test was used to assess whether the variables followed a normal distribution or not. Descriptive statistics such as mean, standard deviation, and median were used for the variables in the measurements. Continuous variables were presented as median (minimum: maximum) and Mean±Standard deviation values. The correlations between ulna distances and angulations were analyzed using a correlation analysis. According to the normality test results the Pearson Correlation Coefficient (rp) or the Spearman Correlation Coefficient (rs) were calculated. Interpretation of correlation analyses was performed according to the study of Mukaka.[9] The SPSS (IBM Corp. Released 2012. IBM SPSS Statistics for Windows, Version 21.0, Armonk, NY: IBM Corp.) was used for statistical analysis and a p-value <0.05 was considered statistically significant.

RESULTS

Distances

The median UL was found to be 251.97 mm (minimum: 196.84 – maximum: 497.76 mm), median PDVA was 82.7 mm (minimum: 16.21 – maximum: 108.62 mm), median DDVA was 169.28 mm (minimum: 107.82 – maximum: 428.98), mean WPVA was 15.04±1.84 mm, mean DAPB was 15.15±1.93 mm, mean DPIB was 13.72±2.37 mm. Table 1 summarizes the distance results of 107 ulnas.

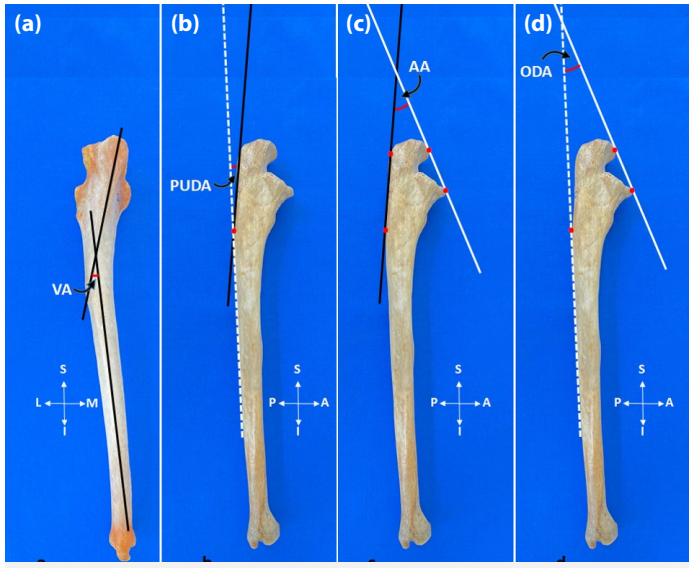

Figure 3. The varus angulation (VA) **(a)**, The red round dot marks the point where the posterior border is angling, the proximal ulna dorsal angulation (PUDA) **(b)**, The articular angle (AA) **(c)**, The olecranon–diaphysis angle (ODA) **(d)**, anterior (A), posterior (P), medial (M), lateral (L), superior (S), inferior (I) left ulna.

Table 1. The data of the proximal ulna distances and angulations (n=107)

Distances (mm)	
UL	251.97 (196.84:497.76)
PDVA	82.7 (16.21:108.62)
DDVA	169.28 (107.82:428.98)
WPVA	15.04±1.84
DAPB	15.15±1.93
DPIB	13.72±2.37
Angulations (°)	
PUTA	27.10±9.04
VA	14 (5:23)
PUDA	8 (-3:20)
AA	25 (19:39)
ODA	17.39±5.33

Data are expressed as mean±standard deviation and median (minimum: maximum). UL: The ulnar length; PDVA: The proximal distance of varus angulation; DDVA: The distal distance of varus angulation; WPVA: The width at the point of varus angulation point; DAPB: Distance between the anterior and posterior border; DPIB: Distance between the posterior and interosseous border; PUTA: Proximal ulna torsion angle; VA: The varus angulation; PUDA: The proximal ulna dorsal angulation; AA: The articular angle; ODA: The olecranon–diaphysis angle.

Angulations

The mean PUTA was 27.10°±9.04°, the median VA was 14° (minimum: 5° – maximum: 23°), the median PUDA was 8° (minimum: -3° – maximum: 20°), the median AA was 25° (minimum: 19° – maximum: 39°), and the average ODA was 17.39°±5.33°.

Correlations

The researchers observed high positive correlations between UL and DDVA (rs=0.83, p<0.001), and WPVA and DAPB (rp=0.77, p<0.001).

A negligible correlation was found between the PUTA and VA (rs=0.28, p=0.003) and a low positive correlation was calculated between the ODA and AA (rs=0.43, p<0.001). Additionally, it was observed that there was a moderate negative correlation between the PUDA and ODA (rs=-0.50, p<0.001). Table 2 shows the correlation results in detail.

DISCUSSION

This study demonstrates proximal ulnar angulations and evaluations of some parameters, including reporting of distal distance of varus angulation (DDVA).

Totlis et al.[10] examined 200 paired ulnae and reported that the mean proximal distance of varus angulation (PDVA) was 8.19±1.26 cm. Beşer et al.[5] evaluated a total of 50 ulnae and stated the mean UL was 250.5±14.9 mm. Similarly, Singh et al.[11] examined 100 dried ulna bones and noted that the total mean UL was 261.1±16.9 mm, and the mean PDVA was 78.7±7.2 mm. Wang et al.[12] analyzed the computed tomography data of 156 ulnas and noted that the mean PDVA was 74 mm. In this paper, the median ulnar length (UL) was 251.97 mm (minimum: 196.84 – maximum: 497.76 mm), median PDVA was 82.7 mm (minimum: 16.21 – maximum: 108.62 mm), median DDVA was 169.28 mm (minimum: 107.82 – maximum: 428.98). These results are highly consistent with the former results of previous studies.

The researchers calculated that the mean WPVA was 15.04±1.84 mm, the mean DAPB was 15.15±1.93 mm and the mean DPIB was 13.72±2.37 mm. The researchers detected only one study related to these values performed by Windisch et al.[13] They recorded the mean WPVA, DAPB, and DPIB values of 16.0 mm, 12.45 mm and 3.53 mm, respectively.

The mean UL, PDVA, and DDVA obtained in this study may serve as reference values in adjusting the length of dorsal plates and intramedullary screws in the Turkish population. In addition, the mean WPVA, DAPB, and DPIB values might guide orthopedic surgeons to adjust the length of the screws to be performed to the point where the VA is located and determine the depth of the screw in that population.

Table 2. The data of the proximal ulna correlations (n=107)

	UL	PDVA	DDVA	WPVA	DAPB	DPIB	PUTA	VA	PUDA	AA	ODA
UL											
r_s	1	0.42	0.83	0.34	0.37	0.22	0.05	0.14	0.372	0.10	0.08
p value	–	<**0.001**	<**0.001**	<**0.001**	<**0.001**	**0.024**	0.605	0.143	0.10	0.316	0.393
PDVA											
r_s	0.42	1	0.04	0.48	0.36	0.43	0.03	0.06	0.228	0.25	0.10
p value	<**0.001**	–	0.698	<**0.001**	<**0.001**	<**0.001**	0.780	0.562	0.25	**0.008**	0.306
DDVA											
r_s	0.83	0.04	1	0.29	0.38	0.21	0.08	0.15	-0.01	0.04	0.08
p value	<**0.001**	0.698	–	0.002	<**0.001**	**0.028**	0.416	0.137	0.884	0.679	0.444
WPVA											
r_p	–	–	–	1	0.77	0.67	0.03	–	–	–	-0.01
r_s	0.34	0.48	0.29	–	–	–	–	0.23	-0.03	0.26	
p value	<**0.001**	<**0.001**	**0.002**	–	<**0.001**	<**0.001**	0.746	0.017	0.769	**0.008**	0.937
DAPB											
r_p	–	–	–	0.77	1	0.55	0.11	–	–	–	0.10
r_s	0.37	0.36	0.38	–	–	–	–	0.27	-0.03	0.28	
p value	<**0.001**	<**0.001**	<**0.001**	<**0.001**	–	<**0.001**	0.283	**0.006**	0.779	**0.003**	0.289
DPIB											
r_p	–	–	–	0.67	0.55	1	0.001	–	–	–	-0.13
r_s	0.22	0.43	0.21	–	–	–	–	0.13	-0.02	0.10	
p value	**0.024**	<**0.001**	**0.028**	<**0.001**	<**0.001**	–	0.990	0.189	0.803	0.285	0.189
PUTA											
r_p	–	–	–	0.03	0.11	0.001	1	–	–	–	0.01
r_s	0.05	0.03	0.08	–	–	–	–	0.28	-0.17	0.10	–
p value	0.605	0.780	0.416	0.746	0.283	0.990	–	0.003	0.083	0.329	0.910
VA											
r_s	0.14	0.06	0.15	0.23	0.27	0.13	0.28	1	-0.15	0.11	-0.03
p value	0.143	0.562	0.137	0.017	**0.006**	0.189	**0.003**	–	0.130	0.258	0.779
PUDA											
r_s	-0.09	-0.12	-0.01	-0.03	-0.03	-0.02	-0.17	-0.15	1	-0.06	-0.50
p value	0.372	0.228	0.884	0.769	0.779	0.803	0.083	0.130	–	0.535	<**0.001**
AA											
r_s	0.10	0.25	0.04	0.26	0.28	0.10	0.10	0.11	-0.06	1	0.43
p value	0.316	**0.008**	0.679	**0.008**	**0.003**	0.285	0.329	0.258	0.535	–	<**0.001**
ODA											
r_p	–	–	–	-0.01	0.10	-0.13	0.01	–	–	–	1
r_s	0.08	0.10	0.08	–	–	–	–	-0.03	-0.50	0.43	–
p value	0.393	0.306	0.444	0.937	0.289	0.189	0.910	0.779	<**0.001**	<**0.001**	–

rp: Pearson correlation coefficient; rs: Spearman correlation coefficient; UL: The ulnar length; PDVA: The proximal distance of varus angulation; DDVA: The distal distance of varus angulation; WPVA: The width at the point of varus angulation point; DAPB: Distance between the anterior and posterior border; DPIB: Distance between the posterior and interosseous border; PUTA: Proximal ulna torsion angle; VA: The varus angulation; PUDA: The proximal ulna dorsal angulation; AA: The articular angle; ODA: The olecranon–diaphysis angle.

Proximal Ulna Torsion Angle (PUTA)

Beşer et al.[5] found that the mean PUTA was 11.1°±6.1°. On the other hand, Yong et al.[14] described this angle as "torsion angulation" and reported that the average torsion was 22.5° on 3D digital images of 20 cadavers. The studies of Öztürk et al.[15] and Aydın Kabakçı[16] noted similar results that ranged from 13.40°±1.23° to 14.64°±8.36°.

Adikrishna et al.[17] examined eight pairs of normal cadaveric ulnae and reported that the average PUTA was 31°±10° (15°–49°). In our study, the mean PUTA was 27.10°±9.04°. The results of the present study are inconsistent with those of the previous studies due to the use of different reference points. One reason why some patients have difficulty performing the normal anatomical functions of the elbow after proximal ulnar prosthesis replacement may be that this angle is overlooked. Therefore, knowing the existence of such an angle and its variations may be important, especially for prosthesis design in fracture fixation for the elbow joint to maintain its normal anatomical function.

Varus Angulation (VA)

The VA has been defined as "the proximal half has a slight curvature that is concave laterally" in the last edition of Gray's Anatomy.[18] Beşer et al.[5] recorded that the mean VA was 9.3° in 50 adult normal ulnae. Totlis et al.[10] reported that the mean angle was 8.48° in 200 paired ulnae specimens. Singh et al.[11] observed the mean VA was 10.78°±2.51° in total samples. Adikrishna et al.[17] evaluated the VA angle differently from other studies and reported that the angle was 167±4° (it is understood that it is equivalent in other studies at 13.0°±4°). Yong et al.[14] stated that the mean VA was 12.1° on 3D CT reconstruction images of 20 cadavers. Shi et al.[8] evaluated 60 patients with proximal ulna fractures who underwent applied open reduction and internal fixation and reported that the mean VA of the ipsilateral (the healthy side) ulna was 12.7°±3.0°, while the VA of the contralateral (the fractured side) ulna was meanly 7.8°±3.0°.

In his study conducted on 82 dry Anatolian ulnas, Erdem[19] noted that the mean VA was 13.82°±3.36°. Öztürk et al.[15] stated that the mean VA was 12.48°±2.42°. Wang et al.[12] stated that the average VA was 16°. Jarvie et al.[20] examined computed tomography images of 59 ulnas and reported that the mean VA was 10.5° (9.8°–11.1°). Aydın Kabakçı[16] examined 62 ulnae and noted that the mean VA was 9.20°±1.85°.

Our median VA was 14° (minimum: 5°-maximum: 23°), which is very close to the mean VA results of the studies of Erdem[19] and Adikrishna et al.[17] Shi et al.[8] showed that repairing the VA of the proximal ulna is important for regaining the range of motion in the forearm. Therefore, we believe that knowing the mean VA in the Turkish population may be important for the recovery of the range of motion in the forearm in this population. Besides, in anatomical olecranon plate applications in this population, we think that the VA angle of this plate should be compatible with our mean VA value.

The Proximal Ulna Dorsal Angulation (PUDA)

Totlis et al.[10] recorded that the mean PUDA was 8.49°±2.69°. Beşer et al.[5] reported a mean PUDA of 8.0°±2.3°. Lenoir et al.[7] stated a median PUDA of 14.9° (11.7° to 16.8°). Adikrishna et al.[17] reported that the average PUDA was 176°±1° (it is understood that it is equivalent in other studies at 4.0°±1°). Savakkanavar and Babu[21] studied bilateral elbow radiographs of 60 patients and reported that the PUDA was meanly 5.6° on the right side and 5.1° on the left side. Jarvie et al.[20] stated that the mean PUDA was 3.7° (2.9°–4.5°). Erdem[19] stated that the mean PUDA (maximum anterior angulation) was 9.12°±4.35°. Yeung et al.[22] reviewed 514 lateral elbow radiographs and found overall median PUDA was 4.7°. In their descriptive study, Soltani et al.[23] used 120 bilateral lateral elbow radiographs and measured the mean PUDA as 1.65°±5.65°. Öztürk et al.[15] examined 25 ulnae and found that the mean PUDA was 5.94°±2.01°. The study conducted by Wang et al.[12] obtained the same PUDA result that was present in 80% of models. Aydın Kabakçı[16] reported that the angle was 5.85°±2.21°. In the present study, the median PUDA was 8° (minimum: -3° – maximum: 20°) Our mean PUDA result is consistent with the result of Beşer et al.[5] The more a fixation tool fits the bone the better.[13] Anatomically preshaped proximal ulna plates have been shown to differ significantly from proximal ulna anatomy.[12] From this perspective, we consider that our mean PUDA value may be a guide in shaping plates consistent with the proximal ulna anatomy in the Turkish population. Additionally, in the case of a complex fracture of the ulna in this population, the average PUDA may be beneficial to orthopedic surgeons in the treatment of such fractures.

The Articular Angle (AA) and the Olecranon–Diaphysis Angle (ODA)

The median AA was found to be 25° (minimum: 19° – maximum: 39°), and the average ODA was 17.39°±5.33°, respectively, in this study. Beşer et al.[5] reported that the mean AA was 27.7°±2.1°, and the mean ODA was 19.3°±2.8°. Singh et al.[11] found that the mean AA as was 8.06°±2.72°. Aydın Kabakçı[16] stated that the mean AA was 20.37°±1.02°, and the mean ODA was 15.49°±3.10°. Our AA and ODA results are very much in line with the AA and ODA results of Beşer et al.[5]

Since the main goal of the surgical application is to provide normal anatomical restoration of the ulna without restricting

the elbow joint,[4] it can be important to consider angles such as AA and ODA in ulnar reconstruction procedures. In this context, we believe that our mean AA and ODA angles may serve as a guide for surgeons during the reconstruction of the proximal ulna in the Turkish population.

Correlations

The researchers obtained significant correlations between the proximal ulna distances (Table 2). During surgical applications for the proximal ulna, a change in the average distances in the ulna may mean a change in the average other distances with which it is associated. Hence, in the reduction of proximal ulna fractures, the existence of these correlations may need to be kept in mind, and bone reconstruction may need to be performed from this perspective.

Aydın Kabakçı[16] stated that there was a negligible correlation between PUTA and PUDA (rp=0.036, r=-0.26). She also reported that there were low positive correlations between the VA and AA (rp=0.008, r=0.33), and the AA and ODA (rp=0.002, r=0.38). There was a negligible correlation between the mean PUTA and VA in our study, so therefore, we think that a change in the mean PUTA may affect the mean VA. Similarly, the presence of a low positive relationship between mean ODA and mean AA in the present paper may indicate the importance of knowing and maintaining these mean angles during surgery. In other words, we believe that the change in mean ODA or AA due to incorrect or incomplete fixation of the proximal ulna may not only affect one of these angles but may also change the other angle. In addition, the moderate negative relationship between the average PUDA and ODA in the present study may mean that a decrease in one of these angles may cause an increase in the other. We think that anatomically preshaped proximal ulna plates should need to be adjusted according to the average PUDA. Otherwise, according to the results of our the present study, not only may the average PUDA change, but the average ODA may also change negatively. In this context, surgical application of the proximal ulna may fail, and complications may develop.

It is well known that some anatomical and physiological changes occur with aging. Since the ages of the ulnas included in the sample were not known, we think that the age distribution of the bones may not be balanced. In this respect, we believe that the correlation results obtained here may vary depending on age. For example, the moderate negative correlation obtained between PUDA and ODA may/may not be stronger in a balanced age group (e.g., between 20–30 ages) or a similar situation may be observed in older age groups. Therefore, we believe that performing correlation analyses of the ulna in a balanced age group would indicate more objective results.

Limitations

The age, sex, and other records of the ulnae were not available in the present study. If the researchers had reached these parameters, more meaningful findings could be obtained.

CONCLUSION

In our study, different from previous studies, the distal distance of varus angulation (DDVA) was measured. The researchers analyzed not only the proximal ulnar angulations (proximal ulna torsion angle (PUTA), varus angulation (VA), proximal ulna dorsal angulation (PUDA), articular angle (AA), olecranon–diaphysis angle (ODA)) but also some lengths and widths. In this context, the possible clinical implications of these anatomical features of proximal ulnar angulations were demonstrated. Moreover, the researchers also investigated the correlation between these angulations and the lengths in more detail and obtained more findings than those of the previous studies.

Consequently, the current study presents proximal ulnar angulations and distances and their correlations with each other in detail in the Turkish population in a large sample of ulnar bones. Although the findings of this paper corroborate many previous anatomical findings, it also examines new anatomical measurements that have not yet been studied and emphasizes the correlation of proximal ulnar angulations with each other. We believe that our measurements of the proximal ulnar angulations may present useful information for orthopedics in the treatment of fractures involving the proximal ulna.

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REFERENCES

1. Masood QM, Qulaghassi M, Grewal U, Bawale R, Kammela M, Singh B. Proximal ulna fractures in adults: A review of diagnosis and. J Clin Orthop Trauma 2021; 20: 101481.

2. Duckworth AD, Carter TH, Chen MJ, Gardner MJ, Watts AC. Olecranon fractures : current treatment concepts. Bone Joint J 2023; 105-B(2): 112–23. [CrossRef]
3. Hopf JC, Nowak TE, Mehler D, Arand C, Gruszka D, Rommens PM. Nailing of proximal ulna fractures: biomechanical comparison of a new locked nail with angular stable plating. Eur J Trauma Emerg Surg 2021; 47(3): 795–802.
4. Siebenlist S, Buchholz A, Braun KF. Fractures of the proximal ulna: current concepts in surgical management. EFORT Open Rev 2019; 4(1): 1–9. [CrossRef]
5. Beşer CG, Demiryürek D, Özsoy H, Erçakmak B, Hayran M, Kızılay O, et al. Redefining the proximal ulna anatomy. Surg Radiol Anat 2014; 36(10): 1023–31. [CrossRef]
6. Chapleau J, Balg F, Harvey EJ, Ménard J, Vauclair F, Laflamme GY, et al. Impact of olecranon fracture malunion: Study on the importance of PUDA (Proximal Ulna Dorsal Angulation). Injury 2016; 47(11): 2520–4. [CrossRef]
7. Lenoir H, Chammas M, Micallef JP, Lazerges C, Waitzenegger T, Coulet B. The effect of the anatomy of the distal humerus and proximal ulna on the positioning of the components in total elbow arthroplasty. Bone Joint J 2015; 97-B(11): 1539–45. [CrossRef]
8. Shi X, Pan T, Wu D, Chen R, Lin Z, Pan J. The impact of varus angulation on proximal fractures of the ulna. BMC Musculoskelet Disord 2018; 19(1): 103. [CrossRef]
9. Mukaka MM. Statistics corner: A guide to appropriate use of correlation coefficient in medical research. Malawi Med J 2012; 24(3): 69–71.
10. Totlis T, Anastasopoulos N, Apostolidis S, Paraskevas G, Terzidis I, Natsis K. Proximal ulna morphometry: which are the "true" anatomical preshaped olecranon plates?. Surg Radiol Anat 2014; 36(10): 1015–22. [CrossRef]
11. Singh J, Pahuja K, Singh T. Morphometric study of proximal ulna with special emphasis on angulations. J Anat Soc India 2015; 64: S12–7. [CrossRef]
12. Wang D, Li J, Xu G, Zhang H, Xu C, Zhang W, et al. Correction to: Morphometric feature description of the proximal ulna based on quantitative measurement: a key consideration for implant design. Surg Radiol Anat 2023; 45(2): 225. Erratum for: Surg Radiol Anat 2023; 45(2): 215–24. [CrossRef]
13. Windisch G, Clement H, Grechenig W, Tesch NP, Pichler W. The anatomy of the proximal ulna. J Shoulder Elbow Surg 2007; 16(5): 661–6. [CrossRef]
14. Yong WJ, Tan J, Adikrishna A, Lee HJ, Jung JW, Cho DW, et al. Morphometric analysis of the proximal ulna using three-dimensional computed tomography and computer-aided design: varus, dorsal, and torsion angulation. Surg Radiol Anat 2014; 36(8): 763–8. [CrossRef]
15. Öztürk K, Özdemir B, Dursun A, Kastamoni Y, Albay S. Anatomical architecture and angulations of the proximal ulna. Med J SDU 2021; 28: 419–26. [CrossRef]
16. Aydın Kabakçı AD. Anatomical structure of the proximal part of the ulna. J Harran Univ Med Fac 2022; 19(2): 412–20. [CrossRef]
17. Adikrishna A, Kim JY, Kekatpure AL, Lee HJ, Kim M, Jeon IH. Dorsal apex curve of the proximal ulna. Acta Orthop Traumatol Turc 2016; 50(1): 97–102. [CrossRef]
18. Standring S, editor. Gray's anatomy: the anatomical basis of clinical practice. 42. edition. China: Elsevier Health Sciences; 2021.
19. Erdem H. Surgical importance of radiographically aided morphometry of the proximal ulna. Int J Morphol 2020; 38(2): 299–304. [CrossRef]
20. Jarvie GC, Kilb B, Willing R, King GJ, Daneshvar P. Apparent proximal ulna dorsal angulation variation due to ulnar rotation. J Orthop Trauma 2019; 33(4): e120–3. [CrossRef]
21. Savakkanavar P, Babu CP. An assessment of proximal ulna dorsal angulation using digital radiographic images. Int J Orthop Sci 2017; 3(2): 26–9. [CrossRef]
22. Yeung CM, Lans J, Kuechle JB, Wright Z, Chang CY, Lozano-Calderón SA. Evaluation of the proximal ulna dorsal angulation for ulnar component sizing in elbow prosthetic reconstruction after distal humeral resection of tumor. J Am Acad Orthop Surg Glob Res Rev 2020; 4(5): e2000062. [CrossRef]
23. Soltani R, Aghajanpour F, Afshar A, Torabi A, Mohammadzadeh E, Farahani RM, et al. Evaluation of the proximal ulna dorsal angulation part and its related factors in radiology images of patients referred to Tehran Hospital in 2018. Res Med 2020; 44(4): 549–53.