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Radiological measurement parameters of distal radius and wrist measured on X-rays in the Turkish population

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ABSTRACT

OBJECTIVE: The aim of our study was to analyze the radiologic morphometry of the distal radius and wrist to assess acceptable limits for restoring normal wrist function after fracture.

METHODS: Radiological measurement parameters were measured retrospectively on anteroposterior and lateral (LAT) wrist radiographs (n=981). Radiological measurement parameters were volar tilt, radial inclination, radial height, ulnar variance, radiocarpal angle, and volar angulation angle. The patients' age, gender, and side of the radiograph were recorded as demographic data.

RESULTS: The mean volar tilt angle was 15.4±4.3 degrees. The mean radial inclination angle in males was 26.8±3.6 degrees. The mean radial height was 13.6±2.1 mm. The mean ulnar variance was 0.8±1.9 mm. One hundred and eighty-nine patients had negative ulnar variances. The mean radiocarpal angle was 12.3±2.7. The mean volar angulation angle was 32.1±6.9 degrees. Radial height was found to be positively correlated with radial inclination ($p<0.001$; r: 601), but it was not significantly correlated with ulnar variance ($p=0.14$).

CONCLUSION: Distal radius fractures are one of the most common types of fractures. Radiological measurement parameters were used in the determination and follow-up of the treatment. The values obtained in this study belong to the Turkish population. These values may be used as reference values in determining the quality of reduction after fracture and in the design of suitable implants for fracture treatment.

Keywords: Anatomy; orthopedics and traumatology; radiology.

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Distal radius fractures are one of the most common injuries in emergency departments and clinical orthopedic practice [1]. The treatment's goals are to restore the native bone anatomy, stabilize the bone during fracture healing, and restore pre-injury wrist functionality [2]. The wrist and distal radius parameters were used to decide which treatment method was appropriate for the patients: radial height and inclination, palmar tilt, and ulnar variance [3]. The decrease in the palmar tilt of the distal radius was shown to increase the loading of the distal radioulnar joint because of increased contact pressure on the articular surface of the distal radioulnar joint [4]. A negative ulnar variance may cause Kienbock disease or avascular necrosis of the lunatum because of increased loading on the radius-lunatum-capitatum-third metacarpal bone [5]. It was shown that the radiocarpal

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joint bore four-fifths of the axial load forcing to the radiocarpal joint. Negative ulnar variance reduces loading on the ulnocarpal joint at the wrist. On the contrary, positive ulnar variance causes increased loading forces at the ulnocarpal joint [6].

Restoring the native distal radius and wrist joint anatomy is necessary when applying different treatment modalities for distal radius fractures. The literature has several studies analyzing the radiographic anatomy of the distal radius and wrist anatomy [7-10]. However, there is a lack of data about the radiologic morphometry of the distal radius and wrist in the Turkish population. Therefore, the aim of our study was to analyze the radiologic morphometry of the distal radius and wrist in our population to determine acceptable limits for restoring normal wrist function following fracture healing.

MATERIALS AND METHODS

This is a retrospective, observational study that was conducted in Istanbul, Turkiye, and was approved by the institutional review board (date: March 05, 2021, decision no. 2752). The study was conducted in accordance with the Declaration of Helsinki. The true wrist anteroposterior (AP) and lateral (LAT) radiographs of the patients who applied to the outpatient clinic of the orthopedics and traumatology department with any complaints of the wrist between January 2019 and June 2021 were evaluated. Patients with a history of wrist fractures, those without true AP and LAT wrist X-rays, those with an open physis, and those with degenerative wrist disorders (arthritis, Kienböck disease, etc.) were excluded from the study. The patients' age, gender, and side of the radiograph were recorded as demographic data.

All radiographs included in the study were taken digitally and were taken in the same radiology department with the same X-ray unit (Drgem Diamond Radiography System, Korea) at the authors' institution. A wrist AP X-ray was taken with the patient in a sitting position, elbow flexed to 90°, and wrist in full pronation. Wrist LAT X-ray was taken with the patient in a sitting position, elbow flexed to 90°, wrist in neutral rotation, and the ulnar aspect of the forearm in contact with the table. All radiographs were taken using calibration and equidistant between the X-ray source and the cassette. The radiologic measurements were performed by two investigators (FB and YB) using picture archiving and communication systems. All measurements were performed with one decimal (length and angle measurements). Interobserver

Highlight key points

- Restoring the native distal radius and wrist joint anatomy is necessary when applying different treatment modalities for distal radius fractures.
- The morphometry of bone structures may vary according to ethnic origins.
- According to the study, volar tilt angle, radial height, radiocarpal angle and volar angulation angle are higher in male gender in Turkish population.
- Radial height was found to be positively correlated with radial inclination.

reliability was >0.80 for all the measurements. The radiologic measurement parameters were volar tilt, radial inclination, radial height, ulnar variance, radiocarpal angle, and volar angulation angle.

Volar Tilt Angle (°)

Two lines were drawn. The first line was drawn tangentially between the dorsal and palmar articular edges of the distal radius, and the second line was drawn perpendicularly to the long axis of the radius at the level of the radial styloid process. The angle between these two lines was measured (Fig. 1A).

Radial Inclination (°)

Two lines were drawn. The first line was drawn from the tip of the radial styloid to the medial edge of the distal radius. The second line was drawn perpendicularly to the longitudinal axis of the distal radius at the level of the lunate fossa. The angle between the two lines was measured as the radial inclination (Fig. 1B).

Ulnar Variance (mm)

Two lines were drawn. The first line was drawn perpendicular to the longitudinal axis of the radius at the level of the distal articular surface of the lunate fossa. The second line was drawn perpendicular to the longitudinal axis of the ulna at the level of the distal cortical margin. The distance between the two lines was measured as an ulnar variance (Fig. 1C). The values were measured as positive if the ulna was longer than the radius.

Radiocarpal Angle (°)

The radiocarpal angle is measured by reference lines. These are the radial centerline and a right-angle line. The radiocarpal angle is the angle formed between this right

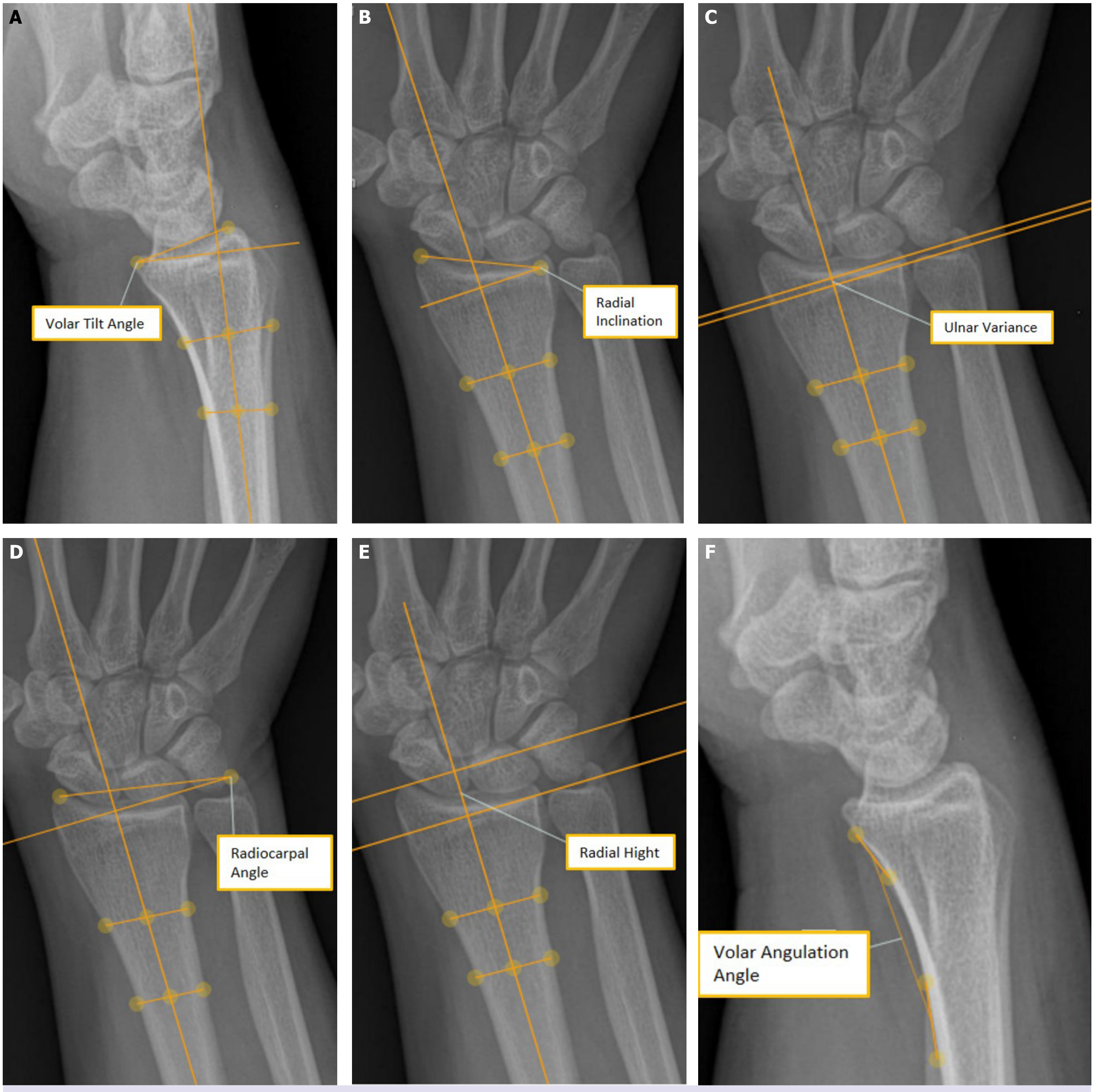

Figure 1. **(A)** Radiological measurement of volar tilt angle. **(B)** Radiological measurement of radial inclination. **(C)** Radiological measurement of ulnar variance. **(D)** Radiological measurement of radiocarpal angle. **(E)** Radiological measurement of radial height. **(F)** Radiological measurement of volar angulation angle.

angle line and a line drawn from the tip of the radial styloid to the tip of the ulnar styloid (Fig. 1D).

Radial Height (mm)

Two parallel lines were drawn. The first line was drawn perpendicular to the longitudinal axis of the radius at the level of the tip of the styloid process. The second line was drawn perpendicular to the long axis of the radius at the level of the lunate fossa. The distance between the two lines was measured as the radial height (Fig. 1E).

TABLE 1. Demographic data of all patients

Number of patients (M/F)	981 (513/468)
Age (years)	39.3±16
Side (left/right)	495/486
Volar tilt angle (degrees)	15.4±4.3
Radial inclination (degrees)	26.7±3.3
Radial height (mm)	13.6±2.1
Ulnar variance (mm)	0.8±1.9
Radiocarpal angle (degrees)	11.6±3.1
Volar angulation angle (degrees)	11.6±3.1

M: Male; F: Female.

Volar Angulation Angle (°)

Two lines were drawn. The first line was drawn tangentially to the radial shaft. The second line was drawn along the distal metaphysis and the volar rim of the distal radius. The angle between these lines was measured as the volar angulation angle (Fig. 1F).

The statistical analysis of the data in our study was performed using SPSS version 21 (IBM Corp., Released 2012. IBM SPSS Statistics for Windows, Version 21.0. Armonk, NY: IBM Corp.,). The numeric values were reported as the mean and standard deviation. The comparison between the two sides and genders was performed using an independent sample t-test for the quantitative values with a normal distribution. The Mann-Whitney U test was used to compare the quantitative values without a normal distribution between the two sides and genders. Pearson correlation analysis was used for the values with normal distribution, and Spearman correlation analysis was used for the values without normal distribution. A $p<0.50$ was considered statistically significant.

RESULTS

Nine hundred and eighty-one patients were included in the study (Table 1). There were 513 (52.3%) male and 468 (47.7%) female patients. The mean age of the patients was 39.3±16 years. The mean volar tilt angle was 15.4±4.3 degrees. The mean volar tilt angle in males was 15.8±4.4 mm, and the mean volar tilt angle in females was 14.9±4.2 mm ($p<0.001$) (Table 2). The average radial inclination was 26.7±3.3 degrees. The mean radial inclination angle in males was 26.8±3.6 degrees, and the mean radial inclination angle in females was 26.5±2.9 degrees ($p=0.26$) (Table 2). The mean radial height was 13.6±2.1 mm. The average radial height in males was 14.2±2.1 mm, and in females, it was 13.1±1.9 mm ($p<0.001$) (Table 2). The mean ulnar variance was 0.8±1.9 mm. The average ulnar variance in males was 0.7±1.8 mm, which was not found to be statistically significant ($p=0.17$) compared to that in females of 0.9±1.9mm (Table 2). One hundred and eighty-nine patients had negative ulnar variances. One hundred and eight (57.1%) of the patients with negative ulnar variance were female, and 81 of them (42.9%) were male (Table 2). The average radiocarpal angle was measured at 11.6±3.1 degrees. The mean radiocarpal angle was 12.3±2.7 degrees in males, which was statistically higher than that in females at 11±3.4 degrees ($p<0.001$) (Table 2). The mean volar angulation angle was 32.1±6.9 degrees. The average volar angulation in males was 33.6±4 degrees, which was statistically higher ($p<0.001$) than in females at 30.8±6.5 degrees (Table 2). Radial height was found to be positively correlated with radial inclination ($p<0.001$; r: 601), but it was not significantly correlated with ulnar variance ($p=0.14$).

TABLE 2. Comparisons of measurements between males and females

	Male (n=513)	Female (n=468)	p
Volar tilt angle (degrees)	15.8±4.4	14.9±4.2	<0.001
Radial inclination (degrees)	26.8±3.6	26.5±2.9	=0.26
Radial height (mm)	14.2±2.1	13.1±1.9	<0.001
Ulnar variance (mm)	0.7±1.8	0.9±1.9	=0.17
Radiocarpal angle (degrees)	12.3±2.7	11±3.4	<0.001
Volar angulation angle (degrees)	33.6±4	30.8±6.5	<0.001

DISCUSSION

Most orthopedic surgeons use acceptable criteria that were reported by Gartland and Werley and thought of as reference values while treating distal radius fractures in their clinical practice [11]. However, bone morphometry could differ in different ethnicities, races, and even genders. Chan et al. [9] reported that the ulnar variance of the Malaysian population was significantly different from that of the Chinese population. Hadi and Wijiono showed that the distal radius morphometry of the Indonesian population was different from that of the Western population and declared the normal ranges of the distal radius morphometries for their population [12]. The change in distal radius morphometry also results in changes in the biomechanics of the wrist joint and the loading of the bones at the wrist. Miyake et al., [13] in their cadaveric study, declared that the load transmission from lunate to radius was not significantly disrupted up to 30° of dorsal angulation at the radiolunate surface. Short et al. [4] also showed that more than 30° of angulation at the radiolunate surface caused more than 50% increased loading to the distal ulna. Gelberman et al. [14] and De Smet [5] both reported that the negative ulnar variance resulted in Kienbock disease. These studies show how important it is to restore the nearly pre-fracture anatomy of the distal radius following DRF.

The mean radial inclination was found to be 26.7 mm in the present study. Mishra et al. [8] observed the mean radial inclination as 23.3 mm, while Chan et al. [9] showed that it was 27 mm in their study population. The Orthopedic Trauma Association (OTA) accepted that the mean radial inclination has to be 23° with a range of 13–30° for acceptable criteria [11]. The mean radial inclination value of our study population was found to be 26.7 mm, with a range of 20–37°. Our results were found to be slightly higher than the generally accepted values in the literature. However, the mean radial inclination value of our population was nearly similar to that measured in the study of Chan et al., [9] which was conducted in the Malaysian population.

The mean palmar tilt in our study was 15.4°. The OTA reference for the acceptable palmar tilt range was from 1 to 21 degrees, and the mean value was observed at 11 [11]. Prithishkumar et al. [15] reported that the mean palmar tilt in their study population was 8.2 mm and 9.1 mm in the right and left radius, respectively. The mean palmar tilt was found to be 12.6° in the study by Chan et al. [9] performed in the Malaysian population. The average palmar tilt of our population was observed to have one of the highest values in the literature. This shows that the palmar tilt could vary in different ethnicities, so the normal values of the contralateral distal radius may be used as the optimum value for every patient.

The mean ulnar variance of our study population was observed to be 0.8±1.9 mm. The OTA reference for the acceptable criteria was declared a neutral variance. Hadi and Wijiono [12] showed an average ulnar variance of -0.4 mm in their study population. In the study of Mishra et al. [8], the mean ulnar variance was 0.66 mm in the Indian population, while Altissimi et al. [16] found a mean value of -2.5 mm. Our study population had a tendency toward positive ulnar variance, and our results for the ulnar variance were consistent with the OTA references.

Gender differences were also evaluated for distal radius morphometry in the literature. Hadi and Wijiono reported that radial inclination, radial height, volar tilt, and ulnar variance showed statistical differences between males and females in their study [12]. Nekkanti et al. [7] and Mishra et al. [8] declared that only radial height showed statistically significant gender differences in their study. We found that volar tilt and radial height were significantly different between males and females; however, radial inclination and ulnar variance measurements were similar in both males and females. The measurements of our study population may be considered consistent with the literature for gender differences in distal radiıs morphometry.

Our study has some limitations. First, our study has a retrospective pattern, so patients with wrist injuries in early childhood could be underestimated and affect the distal radius anatomy. Some ethnic and social differences in the Turkish population might have influenced the results of this study. However, they could not be analyzed because of the retrospective nature of the study. Being a single-center study is another limitation of our study. However, to our knowledge, the present study is the first to evaluate distal radius morphometry measured from standard wrist X-rays in a Turkish population. The values measured in our study could be used while treating distal radius fractures to assess postreduction distal radius morphometry. However, according to the study of Hollevoet et al., [17] the contralateral wrist is the best reference value for an individual for distal radius fracture management rather than population data.

Conclusion

Radiological measurement parameters are important in the treatment plan of distal radius fractures. In this study, the distal radius anatomical parameters of the Turkish population were defined in detail. These values can be used as reference values for determining the treatment modality after fracture, evaluating the quality of reduction after fracture, and designing implants with an appropriate anatomical structure for fracture treatment.

Ethics Committee Approval: The Istanbul Training and Research Hospital Clinical Research Ethics Committee granted approval for this study (date: 05.03.2021, number: 2752).

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