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Radiographic Morphometry of the Distal end Radius in Anatolian Population

Morfometría Radiográfica del Extremo Distal del Radio en la Población de Anatolia

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SUMMARY: Distal radius fractures are one of the most common orthopedic injuries encountered by orthopedic surgeons.. Correction of dorsal tilt and radial height is essential to restore normal biomechanics of the wrist joint. Comprehensive knowledge of the morphometry of the distal radius of the local population becomes critical for the treating surgeon. This study aims to report the morphometry of the distal radius in the Anatolian population and compare it with similar studies in other races and humans. Radiographs of one hundred and twenty-four people were included in the study. Four radiological parameters were examined on all radiographs: radial height, radial tilt, ulnar variance, and palmar tilt. Radial tilt was 23.35°±1.96; palmar tilt was 15.7°±2,87 radial height (mm) was 10.55±4.34, ulnar variance (mm) was 0.32±1.79. The highest rate of negative ulnar variance was found. According to the study's results, reference data varying by race for anatomical fit should be considered in treating DER injuries.

KEY WORDS: Distal radius; Radiological morphometry; Radial tilt; Ulnar variance; Radial height.

INTRODUCTION

Radius distal end (DER) fractures constitute 8-15 % of upper limb traumas (Vardhan *et al*., 2017). Understanding the morphometry of the distal radius; is essential in guiding the fracture pattern, closed reduction of the fracture, plate design of the distal radius, and biomechanics. Anatomical reduction of these fractures is critical in restoring normal function and motion of the wrist joint (Nekkanti *et al*., 2018). Distal radius morphometry is vital to normal wrist biomechanics, studied and reported previously. Radial height, radial tilt, palmar tilt, and ulnar variance are the four critical parameters that define the distal radius morphometry (Chan *et al*., 2008).

Ulnar variance defines the relationship between the lengths of the distal ends of the radius and ulna and, consequently, the relationship between the load carried by these bones (Bu *et al*., 2006). The load distribution on the forearm can vary greatly. For example, in 2 to 3 mm positive ulnar variance wrists, the load distribution along the radius and ulna is 69 % to the radius and 31 % to the ulna. On the other hand, in wrists with 2 mm negative ulnar variance, the distribution is 94 % to the radius and 6 % to the ulna (Casagrande *et al*., 2016).

In clinical practice, orthopedic surgeons primarily accept Gartland Jr. & Werley (1951) morphometric parameter values as a standard for treating DER injuries. However, the morphometric parameters of DER may differ between races. Thus, unaware of this fact, it can be assumed that orthopedists are using the only available Western data on the morphometric parameters of DER (Nekkanti *et al*., 2018).

The use of radiography as a tool to evaluate morphometric measures of DER has been criticized by several authors. The cadaveric study by Johnson & Sazbo (1993) suggested that palmar tilt is affected by rotation. Therefore, in lateral view radiography, it was stated that 5° rotation is responsible for the 1.6° change in palmar tilt (Johnson & Szabo, 1993). Pennock *et al*. (2015) demonstrated the effect of forearm

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rotation on radial curvature, radial height, and palmar curvature. It has been found that supination increases the apparent measurements, and forearm pronation significantly reduces the evident measures (Pennock *et al*., 2005). Therefore, the radiographic study is considered more functional in surgery (Mishra *et al*., 2016).

Differential understanding of the normal distribution of morphometry in a population is essential for clinical practice. DER morphometry is necessary for various situations such as distal radius fracture surgical interventions, distal radius plate design, and kinesiology.

No study has yet been performed on distal radial end radiography in the Anatolian population. We aim to determine the values of the DER anatomy of the Anatolian population and compare it with other countries.

MATERIAL AND METHOD

This study is a retrospective study on radiographic images taken in a tertiary hospital between January 2021 and November 2021. Measurements were made on radiography (PA) of individuals who applied to Training and Research Hospital with wrist chronic wrist pain and without any fracture or mass. Radial inclination, palmer tilt, radial height, ulnar variance, anterior surface measurement data, and demographic data, including age and sex, were collected for each patient. Only accurate posteroanterior (PA) and lateral x-rays (with neutral rotation) were studied. To preserve authenticity, all morphometric measurements were made by single independent personnel. Each parameter was measured three times, and the average value taken was used to reduce the within-observer error.

Radial inclination, radial height, and ulnar variance were measured in the PA view, and palmar tilt was measured in the lateral view. The radiocarpal joint was only included with the fused epiphysis. All radiocarpal joint images showing structural deformity damaged DER (distal radial end) and irregularities due to pathological conditions (such as arthritis) were excluded.

The data were analyzed using SPSS statistical software version 21 for Windows. Comparison of means was carried out using Mann-Whitney U Test, Chi-square test, Kruskal-Wallis Test with significance set at $p<0.05$.

Parameters evaluated included radial inclination, radial height and ulnar variance (Fig. 1), palmar tilt (Fig. 2).

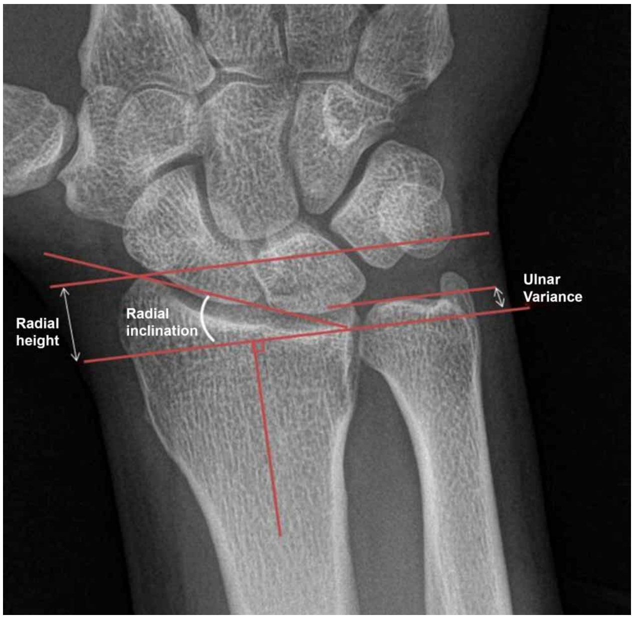

Fig. 1. Radial inclination, radial height and ulnar variance measurement method. Radial inclination is measured as an angle made by tangential line connecting the radial styloid to the edge of the distal radius and the horizontal line perpendicular to the axis of radius at the level of lunate fossa. Ulnar variance is the distance measured between the two horizontal lines. One perpendicular to the axis of ulna at the distal cortical margin and the second line perpendicular to the axis of radius at the distal cortical margin. Radiasl height is the distance measured from the horizontal line (perpendicular to the axis of the radius at the level of lunate fossa) to the horizontal line perpendicular to the axis of the radius at the level of radial styloid proceses.

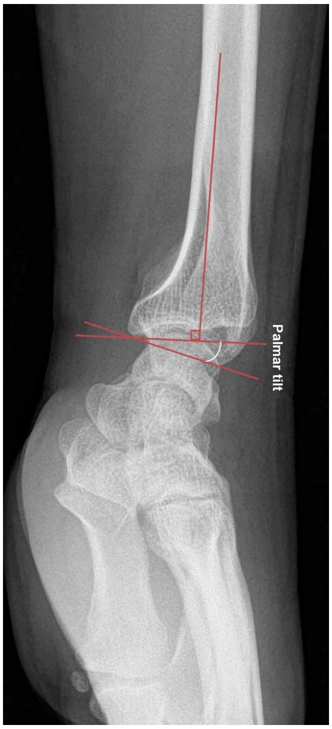

Fig. 2. Depictions of measurement of palmer tilt. MAngle is formed by the meeting of two lines, one tangential line connecting to the dorsal and palmer edge of the articular surface of distal end radius and second line perpendicılar to the long axis of the radius at the level of radial styloid process.

RESULTS

One hundred and twenty-four (n = 124) X-rays were included in this study to analyze. The male and female ratio was 69 (55.6 %) male and 55 (44.4 %) female patients. The age of the patients ranges from 17 to 88 years with an average of 34.69±13.67 standard deviation (SD) years old.

When the data of the study were evaluated in general, radial inclination angle was 23.35±1.96; palmar tilt angle was 15.7±2.87, radial height (mm) was 10.55±4.34, ulnar variance (mm) was 0.32±1.79 (Table I). When the data were compared by sex, only radial height values showed a significant difference (p<0.001) (Table II).

Table I. Distribution of radial height, radial inclination, palmar tilt and ulnar variance of subjects.

Parameters	Mean±SD (range)
Radial inclination (°) (range)	23.35±1.96 (18.5-28.5)
Palmar tilt (°) (range)	15.7±2.87 (21.8-10.8)
Radial height (mm) (range	10.55±4.34 (0,86-16.5)
Ulnar variance (mm) (range)	0.32±1.79 (-3.7-+3.7)

Table II. Distribution of radial height, radial inclination, palmar tilt and ulnar variance according to sex.

Parameters	Male	Female	*P*
Radial inclination (°) (range)	23.4±1.99	23.2±1.90	>0.05
Palmar tilt (°) (range)	14.6±3.09	15.4±2.57	>0.05
Radial height (mm) (range)	12.8±4.58	11.2±3.89	<0.001*
Ulnar variance (mm) (range)	0.34±1.83	0.30±1.75	>0.05

* There is a significant difference between the sexes.

When ulnar variance was compared according to sex, negative and positive ulnar variance rates were close to each other in male and female groups. Both groups had at least neutral ulnar variance. No statistically significant difference was found in comparing ulnar variance between the sexes (Table III).

Table III. Distribution of ulnar variance according to sex.

Ulnar variance	Male (%)	Female (%)
negative	31 (44.9)	23 (42)
neutral	8 (11.6)	10 (18)
positive	30 (43.5)	22 (40)

There was no significant difference between the groups. p = 0.585

When DER values were evaluated according to age, no significant difference was found (Table IV). When ulnar variance was estimated between age groups, 50 % negative ulnar variance and 12.5 % neutral ulnar variance were found in the 17-29 age group. In the 30-59 age group, 42 % of the ulnar variances were positive, and 17.7 % of them were neutral ulnar variances. While there was 83.3 % positive ulnar variance in the age group of 60 ≤, neutral variance (0 %) was not found. There was no statistically significant difference between the groups (Table V).

Table IV. Distribution of radial height, radial inclination, palmar tilt and ulnar variance according to age group

Parameters	17-29	30-59	60≤	*P*
Radial inclination (°)	23.51±2.06	23.25±1.52	22.78±2.52	0.49
Palmar tilt (°)	15.71±3.03	15,8±2.68	15.95±3.74	0.94
Radial height (mm)	10.67±4.21	10.45±4.49	10.34±4.82	0,85

There was no significant difference between the groups.

Table V. Distribution of ulnar variance according to age group.

Parameters	17-29 (%)	30-59 (%)	60≤ (%)
negative	28 (50)	25 (40.3)	1 (16.7)
neutral	7 (12.5)	11 (17.7)	0
positive	21 (37.5)	26 (42)	5 (83.3)

There was no significant difference between the groups. p = 0.209

A comparison of these studies with other DER studies is given in Table VI. DER values differ between different studies and this study.

Comparisons were made with the Anatolian population and other previously studied populations. It was observed that there was a difference in DER values between the different populations and the Anatolian population (Table VII).

DISCUSSION

Distal radius fractures are a common orthopedic injury that accounts for every six fractures diagnosed and treated in emergency departments (Pennock *et al*., 2005). Knowledge of average values of distal morphometry is essential, as one of the goals of fracture treatment is to reconstruct the anatomical configuration (Jupier & Masem, 1988). The quality of reduction is mainly evaluated by the radial inclination angle and the degree of restoration of the palmar tilt (van Earten *et al*., 2008). Radial shortening increases radial inclination, and dorsal angulation causes significant changes in wrist joint kinematics and grip strength (Gupta *et al*., 2015).

Short *et al*. (1987) in a cadaveric study demonstrating the importance of palmar tilt, increased dorsal angulation was shown to increase the load passing through the ulna. Loss of radial height and radial inclination results in significant axial load transfer from the radius to the ulna. Loss of palmar tilt reduces the area of contact of the distal articular surface with the scaphoid and lunate (Short *et al*., 1987). These changes can cause post-traumatic osteoarthritis, midcarpal instability, and pain. In addition, loss of palmar tilt weakens grip strength and causes distal radioulnar joint incompatibility, which tightens the interosseous membrane and limits forearm rotation (Caputo *et al*., 1998). Based on these findings, guidelines have been created that determines the amount of malalignment a patient can tolerate. In general, fractures that result in a radial height loss of more than 2 mm, radial inclination changes of more than 5°, and a loss of palmar tilt of more than 10° require reduction (Van Riet *et al*., 2004).

When the study data were compared with the Orthopedic Trauma Association (OTA), The usual range of the radial inclination value is considered to be between 13-20° in OTA. In the Anatolian population, this value was found to be 23.35°. While the normal range of palmar tilt value was accepted as 1-21°, it was 15.7° in the Anatolian population. While the average value range of radial height is taken as 11-13 mm, this value was 10.55 mm in the Anatolian population. While ulnar variance was considered neutral in OTA, it was found to be negative variance in the Anatolian population. While all DER values are within the normal range according to OTA, only the ulnar variance differs from the value accepted by the Anatolian population.

Avascular necrosis of the lunate, avascular necrosis of the scaphoid, and negative ulnar variance area on scaphoid-lunate dissociation have been demonstrated in previous studies (De Smet, 1994). Gelberman *et al*. (1975) found that negative ulnar variance was responsible for Kienbock's disease, more common in whites. Conversely, positive ulnar variance causes overload on the ulnar compartment, resulting in triangular fibrocartilage complex (TFCC) degeneration and degeneration of other carpal bone cartilage. Decreased radial height has been found to impair TFCC and cause significant discomfort in kinematics around the wrist. Although it caused this discomfort in changes in radial inclination, it was not as effective (Adams, 1983).

In our study, when DER values were compared between sexes, radial height was higher in males, a significant difference. There is no significant difference between other values (Table II). Mishra *et al*. (2016) are similar to the results found.

When the ulnar variance values are compared, there is no significant difference between the sexes. The highest rate of negative variance and the least rate of neutral variance were found in men and women (Table III). Nekkanti *et al*. (2018) in their study, the highest neutral variance in men and women and the least positive variance was found. In our study, mean ulnar variance was observed in 54 patients (43.54 %), negative variance, positive variance in 52 patients (41.9 %), and neutral variance in 18 patients (14.56 %). The OTA reference value for ulnar variance is neutral variance. Chan *et al*. (2008) observed that the mean ulnar variance had a positive variance of 0.13 ± 0.72 mm. Mishra *et al*. (2016) observed a positive ulnar variance of 0.66 ± 2.46 mm in their study of the Indian population. However, the tendency for negative ulnar variance was higher in our study. There was a positive ulnar variance trend in the second rank, and the least neutral variance was found.

When DER values were evaluated according to age, no significant difference was found between radial inclination, palmar tilt, and radial heights; however, in the

Table VI. Comparison between this series and other previously published studies.

Parameters	Nalbant *et.al*., 2022	Nekkanti *et. al*., 2018	Mishra *et al*., 2016	Gupta *et al*., 2015	Hadi *et al*., 2013	Prithishkumar *et al*., 2012	Chan *et al*, 2008	Schuind *et al*.,1992	Werner *et al*.,1992	Altissimi *et al*., 1986	Gartland & Werley 1951
Radial inclination (°)	23.35±1.96 (18.5-28.5)	21.58 ± 3.35	23.27±7.42 (11.3-42.1)	Total: 25.05 Left: 24.0 Right: 25.6	Not reported	Left:21.8±2.5 Right:22.1 ± 2.9	27 ± 3.18	24 (19-29)	30	16-28	23 (13 – 30)
Palmar tilt (°)	15.7±2.87 (21.8-10.8)	10.92 ± 2.86 to 11.62 ± 3.30	10.07±5.28 (1-16.9)	Not reported	Not reported	Left: 8.2 ± 2.9 Right: 9.1±2.0	13.0 ± 3.57	Not reported	6	0-18	11 (1-21)
Radial height (mm)	10.55±4.34 (0,86-16.5)	8.8 ± 2.6	11.31±4.9 (7.1-30.4)	Left: 10±0.13 Right: 9.7±0.14	11.36± 1.66	Left: 11±1.4 Right: 10.8±1.5	Not reported	Not reported	Not reported	Not reported	Not reported
Ulnar variance (mm)	0.32±1.79 (-3.7-+3.7) Neutral (14.53%) Negative (43.54%) Positive (41.93%)	Neutral (56.7%) Negative (34.8%) Positive (8.4%)	0.66±2.46 (-2.4, +4.1)	Not reported	Not reported	Not reported	0.13 ± 0.70	-4.2±2.3	-4.01±1.4	-2.5±3.1	Not reported

Table VII. Distribution of radial inclination, palmar tilt and ulnar variance according to race.

Parameter	Anatolian	Malay	Indian	Chinese	Others
Radial inclination (°)	23.35±1.96	24.8 ± 3.03	27.0 ± 3.18	24.1 ± 3.77	22.8 ± 3.87
Palmar tilt (°)	15.7±2.87	12.9 ± 3.78	13.0 ± 3.57	11.8 ± 2.77	10.5 ± 3.15
Ulnar variance (mm)	0.32±1.79	0.18 ± 1.28	0.13 ± 0.70	-0.75 ± 1.42	-0.8 ± 2.14

Anatolian population and Nekkanti *et al*. (2008) compared the data in their study with the Indian population; While the radial inclination of the Anatolian population was found to be 23.51°±2.06 in the 17-29 age group, 23.25°± 1.52 in the 30-59 age group, 22.78°± 2.52 in the 60 ≤ age group, in India it was 21.83° ±3.56 in the 30 ≤ age group, and in the 31-60 age group. It was found as 21.46°± 3.04, 21.08°±3.78 in the 60 ≤ age group. Radial height in the Anatolian population by age; While was found to be 10.67 mm ±4.21 in the 17-29 age group, 10.45 mm ±4.49 in the 30-59 age group, 10.34 mm ±4.82 in the 60 ≤ age group. In the Indian population, 9 mm ±0.28 in the 30 ≤ age group, 8.8 mm ±0.26 in the 31-60 age group, 8.2 mm ±0.23 in the age group of 60 ≤. Palmar tilt was found to be in the Anatolian population 15.71°±3.03 in the 17-29 age group, 11.43°±3.28 in the 30 ≤ age group, 11.42°±3 in the 31-60 age group, 10.64°±3.14 in the 60 ≤ age group, while in the Indian population 11.43 in the 30 ≤ age group. It was found as ± 3.28, 11.42 ± 3.00 in the 31-60 age group, and 10.64 ± 3.14 in the 60 ≤ age group. This comparison shows the DER differences between the Anatolian and Indian populations.

When the ulnar variance was evaluated according to age, the negative variance in the Anatolian population was 50 % in the 17-29 age group, 40.3 % in the 30-59 age group, and 16.5 % in the 60 ≤ age group. Nekkanti *et al*. (2008) found a negative variance in their study 48.6 % in the 30 ≤ age group in the Indian population, 36.9 % in the 31-60 age group, and 19.2 % in the 60 ≤ age group. In the Anatolian population, the positive variance was 37.5 % in the 17-29 age group, 42 % in the 30-59 age group, and 83.3 % in the 60 ≤ age group, while the positive variance in the Indian population was 11.2 % in the 30 ≤ age group, 11.4 % in the 31-60 age group, and 15.4 % in the 60 ≤ age group. In the Anatolian population, the neutral variance was 12.5 % in the 17-29 age group, 17.7 % in the 30-59 age group, while no neutral variance was found in the 60 ≤ age group. In the Indian population, the neutral variance was 40.2 % in the 30 ≤ age group, 51.7 % in the 31-60 age group, and 65.4 % in the 60 ≤ age group. While the Anatolian population tended to have more negative ulnar variance, it was determined that the Indian population tended to have more neutral ulnar variance.

In treating distal radius fractures, surgeons use the current reference values of Gartland Jr. & Werley (1951) as standard. However, the authors think morphometric parameters vary from country to country, race, ethnicity, and patient structure. Therefore, unawareness of this fact may be why orthopedists adopt the only available Western data of the morphometric parameters of the DER (Nekkanti *et al*., 2018). Chan *et al*. (2008) found that ulnar variance was statistically significant in the Chinese and Malaysian populations (Chan *et al*., 2008; Hadi & Wijiono, 2013). In this study, when the Anatolian population and other populations are compared, there is a difference in the DER values of the Anatolian population. As can be understood from the comparison in the table, the Anatolian population differs according to India, Malaysia, China, and other countries (Table VII).

Distal radius morphometry is an essential factor in the clinical setting. Therefore, it is necessary to know the average values of the distal morphometry, as one of the goals of fracture management is to restore anatomical alignment. In addition, positive ulnar variance is considered one of the possible factors predisposing to Kienbock's disease (Chan *et al*., 2008). The earliest effect of fused distal radius fractures on the normal biomechanics of the wrist joint was described by Gartland Jr. & Werley (1951). Scoring systems have been widely used to evaluate the functional outcomes of the treatment of distal radius fractures. As a result of the clinical studies of DER conducted to date, the importance of restoring the normal alignment of the distal radius in the event of a fracture has been emphasized (Taleisnik & Watson, 1984; Altissimi *et al*. 1986; Porter & Stockley, 1987; Beumer & Lindau, 2014).

The limitation of our study was that the number of images in the appropriate position and the desired criteria was low since the study was retrospective. There were also images of one side, and no right-to-left comparisons were made. However, Mishra *et al*. (2016) in their study, stated that they did not find a significant difference between the right and left arms.

As observed in our study, the standard parameters differ significantly from the Anatolian, West, and East Asian populations. Therefore, there is a need to examine each race and report normal radiological parameters of the distal radius.

CONCLUSION

This study shows that the morphometry of the distal radius in the Anatolian population has different values from other populations. The data can be used for anatomical alignment when treating DER injuries in the Anatolian population. A clear understanding of the normal distribution of morphometry in a population group is essential for clinical practice. Studies with a larger population may give better details in defining standard parameters for the Anatolian population. Knowing the variations of these parameters in the local population allows the treating surgeon to be more efficient and comprehensive in treating these common fractures.

ETHICS APPROVAL. The approval of the study was obtained from our institution Ethics Committee. (Decision No:177 Research No:123 Date:25.12.2020)

NALBANT, A.; ISMAILOGLU, E.; TURHAN, E.; BEDRE DUYGU, Ö. Morfometría radiográfica del extremo distal del radio en la población de Anatolia. *Int. J. Morphol., 41(1)*:297-302, 2023.

RESUMEN: Las fracturas de la parte distal del radio son probablemente las lesiones ortopédicas más comunes que encuentran los cirujanos ortopédicos. La corrección de la inclinación dorsal y la altura radial es esencial para restaurar la biomecánica normal de la articulación de la muñeca. El conocimiento integral de la morfometría del radio distal de la población local es importante para el cirujano tratante. Este estudio tuvo como objetivo reportar la morfometría de la parte rdistal del radio en la población de Anatolia y compararla con estudios similares en otras razas y humanos. Se incluyeron ciento veinticuatro radiografías simples consecutivas de la articulación de la muñeca. Se examinaron cuatro parámetros radiológicos: altura radial, inclinación radial, variación ulnar e inclinación palmar. El ángulo de inclinación radial fue de 23,35±1,96; el ángulo de inclinación palmar fue de 15,7±, la altura radial (mm) fue de 10,55±4,34, la varianza ulnar (mm) fue de 0,32±1,79. Se encontró la tasa más alta de varianza ulnar negativa (43,5 %). Los resultados de este estudio deben tenerse en consideración al tratar fracturas de la parte distal del radio, con datos de referencia que varían según la raza para el ajuste anatómico.

PALABRAS CLAVE: Radio distal; Morfometría radiológica; Inclinación radial; Variación ulnar; Altura radial.

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