The Radiographic Morphometry Of The Distal End Radius İn Anatolian Population

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Abstract

Introduction: Distal radius fractures are arguably 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. 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.

Methods: One hundred and twenty-four consecutive plain radiographs of the wrist joint were included. Radiographs that were not centered or rotated to the wrist joint were excluded from the study. Four radiological parameters were examined on all radiographs: radial height, radial tilt, ulnar variance, and palmar tilt. Only radiographs with fused physiques of the distal radius were considered.

Results: Radial tilt angle was 23.35±1.96, palmar tilt angle was 15.7±, radial height (mm) was 10.55±4.34, ulnar variance (mm) was 0.32±1.79 (Table 1). When the data were compared with gender, only radial height values showed a significant difference ($p<0.001$). The highest rate of negative ulnar variance was found (43.5%).

Conclusion: Distal radius morphometry varies according to the patient's race, ethnicity, and structure. Comprehensive knowledge of the morphometry of the distal radius of the local population becomes critical for the treating surgeon. The results of this study can also be used as reference data for anatomical fit when treating DER injuries in the Anatolian population.

Introduction

Radius distal end (DER) fractures constitute 8–15% of upper extremity traumas (Varhan 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). 1994).

In clinical practice, orthopedic surgeons primarily accept Gartland and Werley's 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 and Sazbo 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 and Szabo, 1993). Pennock et al. (2005) demonstrated the effect of forearm 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 Method

This is a retrospective study carried out at a tertiary care hospital from January 2021 to November 2021. Measurements were made on radiography (PA) of individuals who applied to Training and Research Hospital with wrist trauma and 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 gender, 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).

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 1). When the data were compared by gender, only radial height values showed a significant difference (p < 0.001) (Table 2).

Table 1
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 2
Distribution of radial height, radial inclination, palmar tilt and ulnar variance according to gender.

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 genders.			

When ulnar variance was compared according to gender, 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 3).

Table 3
Distribution of ulnar variance according to gender

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 4). 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 5).

Table 4
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 5
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			

Comparison of these studies with other DER studies was compared in Table 6. DER values differed between different studies and this study.

Table 6
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 and 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

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 7).

Table 7
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

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 and 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).

In 1987 Short et al. 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 found that negative ulnar variance was responsible for Kienbock's disease, more common in whites (Gelberman et al., 1975). 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 genders, radial height was higher in males, a significant difference. There is no significant difference between other values (Table 2). Mishra et al. (2016) are similar to the results found.

When the ulnar variance values are compared, there is no significant difference between the genders. The highest rate of negative variance and the least rate of neutral variance were found in men and women (Table 3). Nekkanti et al. 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 Anatolian population and Nekkanti et al. (2018) 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. 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 and Werley as standard (Gartland and Werley, 1951). 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 (Hadi and Wijiono, 2013; Chan et al., 2008). 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 (Tables 6 and 7).

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 and Werley in 1951 (Gartland and 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 and Watson, 1984; Altissimi et al. 1986; Porter and Stockley, 1987; Beumer and 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.

Declarations

Ethics approval: The approval of the study was obtained from İzmir Bakırçay University Ethics Committee. (Decision No:177 Research No:123 Date:25.12.2020)

Conflict of Interest: The authors declare no competing interests

Author Contribution: AN; Project development, Data Collection, Data analysis, Manuscript writing. Eİ; Data Collection, Data analysis. ET; Project development, Data analysis. ÖBD; Data Collection, Data analysis

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References

1. Vardhan H, Kumari R, Chouhan SK. Anatomy of distal end of radius: A radiological study done on adult population of Jharkhand state of India. International Journal of Medical and Health Research 2017;3:119–20
2. Nekkanti S, Shah J, Mudundi D, Sakhuja V, Shankar V, Chandru V. A study of the radiographic morphometry of the distal radius in a south Indian population. Hand Microsurg. 2018; 7(1): 9–15doi: 10.5455/handmicrosurg.285986

3. Chan CYW, Vivek AS, Leong WH, Rukmanikanthan S. Distal radius morphometry in the malaysian population. Malays Orthop J 2008;2:27–30.
4. Bu J, Patterson RM, Morris R, Yang J, Viegas SF. The effect of radial shortening on wrist joint mechanics in cadaver specimens with inherent differences in ulnar variance. J Hand Surg Am. 2006;31(10):1594e1600.
5. Casagrande DJ, Morris RP, Carayannopoulos NL, Buford WL. Relationship Between Ulnar Variance, Cortical Bone Density, and Load to Failure in the Distal Radius at the Typical Site of Fracture Initiation. J Hand Surg Am. 2016 Dec;41(12):e461-e468.
6. De Smet L. Ulnar variance: facts and fiction review article. Acta Orthop Belg 1994;60:1–9.
7. Johnson PG and Szabo RM. 1993. Angle measurements of the distal radius: a cadaver study. Skeletal Radiology 22 (4): 243–246
8. Pennock AT, Phillips CS, Matzon JL, Daley E. 2005. The effects of forearm rotation on three wrist measurements: radial inclination, radial height and palmar tilt. Hand Surg 10(1):17–22
9. Mishra PK, Nagar M, Gaur SC, Gupta A. Morphometry of distal end radius in the Indian population: A radiological study. Indian J Orthop. 2016 Nov-Dec;50(6):610–615. doi: 10.4103/0019-5413.193482. PMID: 27904215; PMCID: PMC5122255
10. Jupier JB, Masem M. Reconstruction of post–traumatic deformity of the distal radius and ulna. Hand Clin 1988;4:377–90
11. van Earten PV, Lindeboom R, Oosterkamp AE, Goslings JC. An X–ray template assessment for distal radial fractures. Arch Orthop Trauma Surg 2008;128:217–21
12. Gupta C, Kalthur SG, Malsawmzuali JC, D'souza AS. A morphological and morphometric study of proximal and distal ends of dry radii with its clinical implications. Biomed J. 2015 Jul-Aug;38(4):323-8. doi: 10.4103/2319-4170.151033. PMID: 25673172.
13. Short WH, Palmer AK, Werner FW, Murphy DJ, A biomechanical study of distal radius fractures, J Hand Surg 12A:529–534, 1987
14. Caputo AE, Mazzocca AD, Santoro VM. The nonarticulating portion of the radial head: Anatomic and clinical correlations for internal fixation. J Hand Surg Am 1998;23:1082–90
15. Van Riet RP, Van Glabbeek F, Neale PG, Bimmel R, Bortier H Morrey BF, *et al*. Anatomical considerations of the radius. Clin Anat 2004;17:564–9.
16. Gelberman RH, Salamon PB, Jurist JM, Posch JL. Ulnar variance in Kienböck's disease. J Bone Joint Surg Am 1975;57:674–6.
17. Adams BD. Effects of radial deformity on distal radioulnar joint mechanics. J Hand Surg Am 1993;18:492–8.
18. Gartland JJ, Werley CW. Evaluation of healed Colles' fractures. J Bone Joint Surg Am 1951;33A:895–907.
19. Hadi S, Wijiono W. Distal radius morphometry of Indonesian population. Med J Indonesia 2013;22:173–7.
20. Taleisnik J, Watson HK. Midcarpal instability caused by malunited fractures of the distal radius. J Hand Surg Am 1984;9:350–7.
21. Altissimi M, Antenucci R, Fiacca C, Mancini GB. Long-term results of conservative treatment of fractures of the distal radius. Clin Orthop Relat Res 1986;206:202–10.
22. Porter M, Stockley I. Fractures of the distal radius. Intermediate and end results in relation to radiologic parameters. Clin Orthop Relat Res 1987;220:241–52
23. Beumer A, Lindau TR. Grip strength ratio: a grip strength measurement that correlates well with DASH score in different hand/wrist conditions. BMC Musculoskelet Disord 2014;15:336

Figures

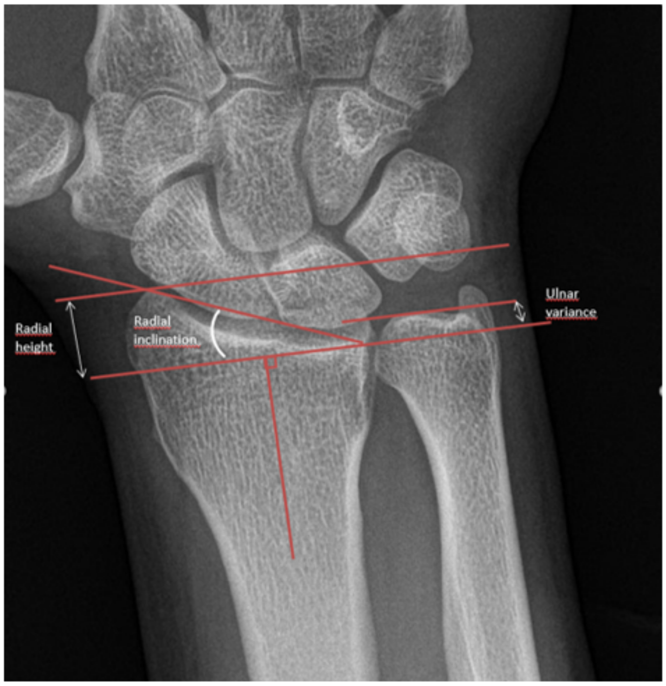

Figure 1

Radial inclination, radial height and ulnar variance.

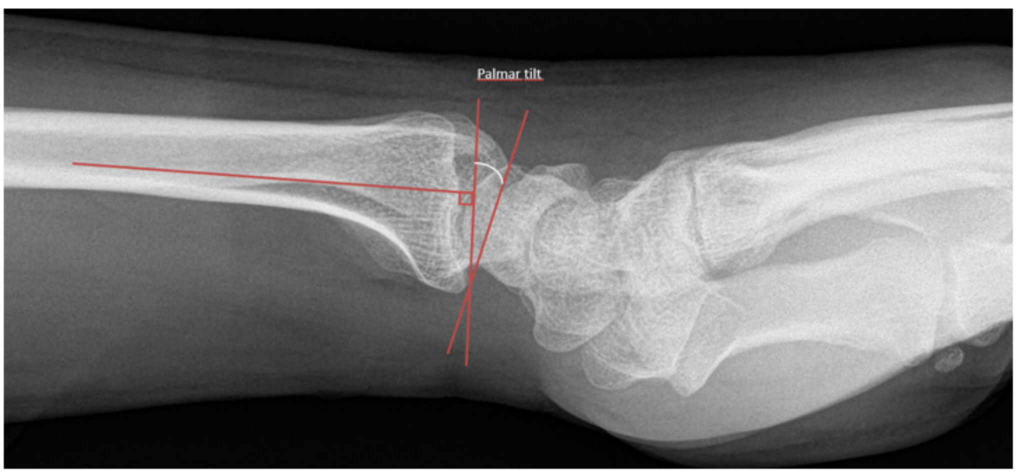

Figure 2

Palmar tilt