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Distal Radius Measurements in Indian Population-An comprehensive Morphometrical Analysis

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ABSTRACT

The four basic morphometrical parameters regarding the anatomy of the distal end of radius bone are radial inclination, palmar tilt/volar tilt, radial height (length) and ulnar variance. The management of various conditions such as fracture of the distal radius bone, designing of the distal radius plates and kinesiology utilize the parameters in the morphometrical measurement of the distal end radius. The goal of our study is to bring about the normalized values of the morphometrical parameters of the DER among the general Indian population for helping in designing the distal radius plates. The study was conducted in a tertiary care hospital in India. It was a single hospital based study. The views considered for the study were the true posteroanterior (PA) and the lateral view (with neutral rotation). The posteroanterior view was used for the measurement of radial inclination, radial length (height) and the ulnar variance. The lateral view helped in the accomplishment of the measurement of the palmar/volar tilt. The statistical analysis was done by Microsoft Excel 2007 (Data add in function was installed for the analysis of the collected data). The means of the morphometrical parameters was compared with the help of T-test. Two hundred (n=200) radiographs were included for analysis under this study. The mean value of radial inclination was 20.7 8 ° ± (SD) 3.45° [Range: 14.9-29.1°], palmar/volar tilt 10.99° ± (SD) 3.87° [Range: 1.8-18.6°], radial length/height 11.39 mm ± (SD) 1.97 mm [Range: 8.3-27.7 mm], and ulnar variance 0.90 mm ± (SD) 3.14 mm [Range: +0.70 to +3.70]. This study will lead for further researches in the analysis of the morphometrical parameters of the distal end of radius bone in the Indian population. For the clinical management of the injuries around the wrist joint the results of this study can be used as a reference standard to anatomically align the bones and the affected structures.

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INTRODUCTION

The four basic morphometrical parameters regarding the anatomy of the distal end of radius bone are radial inclination, palmar tilt/volar tilt, radial height (length) and ulnar variance (Mishra *et al.*, 2016). The evaluation of fracture reduction of distal end radius [DER] is based upon the restoration of the radial inclination and palmar tilt of the forearm before the occurrence of the fracture (Eerten *et al.*, 2008). The grip strength of the wrist joint and its kinesiology is influenced by the alterations

in the radial height [length] in association with the changes in the palmar tilt (Leung *et al.*, 2000; Slutsky, 2005). One of the important parameters in the management of the fracture of the DER is the ulnar variance (Ando *et al.*, 2006). Thus, the parameters involved in the morphometrical measurement of the DER are radial inclination, palmar/volar tilt, radial length (height), and ulnar variance. The management of various conditions such as fracture of the distal radius bone, designing of the distal radius plates and kinesiology utilise the parameters in the morphometrical measurement of the distal end radius (Mishra *et al.*, 2016).

The correlation between the anatomical measurements of the DER and the functional status achieved as the end result of management has been a topic of interest for the researchers. This also plays a vital role in planning and executing the management process of the ailment occurring at the DER (Hollevoet and Verdonk, 2003). The researches done for the morphometrical parameters of the DER are less compared to other major bones among the Indian population (Prithishkumar *et al.*, 2012; Gupta *et al.*, 2015). Therefore, there is imminent requirement for the knowledge regarding the morphometrical parameters for the management of the conditions occurring in the DER. The goal of our study is to bring about the normalized values of the morphometrical parameters of the DER among the general Indian population for helping in designing the distal radius plates.

MATERIALS AND METHODS

The study was conducted in a tertiary care hospital in India. It was a single hospital based study. The study was carried out during the period from January 2020 to March 2020. The wrist radiographs of the patients with wrist joint related ailments were collected. The morphometrical parameters included under the study were the radial inclination, palmar/volar tilt, radial length (height) and ulnar variance.

Only those wrists with the fused epiphysis were taken for the study. Those wrists with unfused epiphysis, unossified bone, structural deformity irregularities, and pathological conditions such as arthritis were excluded from the study. Because, these factors may be responsible for the alterations in the measurement of the morphological parameters. The comparison of the morphometrical values between the right and left hand was also done.

The wrist radiographs were taken following the standard protocols. The views considered for the study were the true posteroanterior (PA) and the lateral view (with neutral rotation). Those radiographs that were not centred over the wrist for the posteroanterior view and those with rotation for the lateral view were excluded.

The authenticity of the study was maintained and the inter observer errors were avoided by measuring all the morphometrical parameters by a single independent person. The posteroanterior view was used for the measurement of radial inclination, radial length (height) and the ulnar variance. The lateral view helped in the accomplishment of the measurement of the palmar/volar tilt. The statistical analysis was done by Microsoft Excel 2007 (Data add in function was installed for the analysis of the collected data). The means of the morphometrical parameters was compared with the help of T-test. P value lesser than 0.05 (<0.05) was set for the level of significance. Data was analysed as an entire population in a whole group. The analysis was also carried out in specific subgroups. Male population was compared with female population. Left hand was compared with right hand.

Radial Inclination

For subtending the angle of radial inclination on PA view, first a line from the tip of the radial styloid of the radius to the medial edge of the distal radius (line A-B) then the second horizontal line is drawn (line B- C) perpendicular to the longitudinal axis of the radius (line D- E) at the level of the lunate fossa (Figure 1). Thus, the subtended angle (<ABC=<a) is the angle of radial inclination.

Radial Length/Height

For measuring radial height in PA view, the first horizontal line (line A-B) drawn on the line perpendicular to the long axis of the radius (line C-D) passing through the distal tip of the radial styloid, and the second horizontal line drawn to perpendicular to the long axis of the radius (line E-F) passing through the lunate fossa (Figure 2). Now, the length (h) between the two horizontal lines (line A- B to line E- F) is radial height.

Ulnar variance

Ulnar variance was measured on PA radiographs. It is the distance (h) measured between the line A- B drawn at the cortical margin (perpendicular to the long axis, line E- F) of the distal ulna relative to the line C- D drawn at the cortical margin (perpendicular to the long axis, line G- H) of the distal radius (Figure 3). Measured values of ulnar variance were designated as positive or negative according to the relative distal or proximal position of the distal ulnar cortical margin (compared to the distal radial cortical margin), respectively.

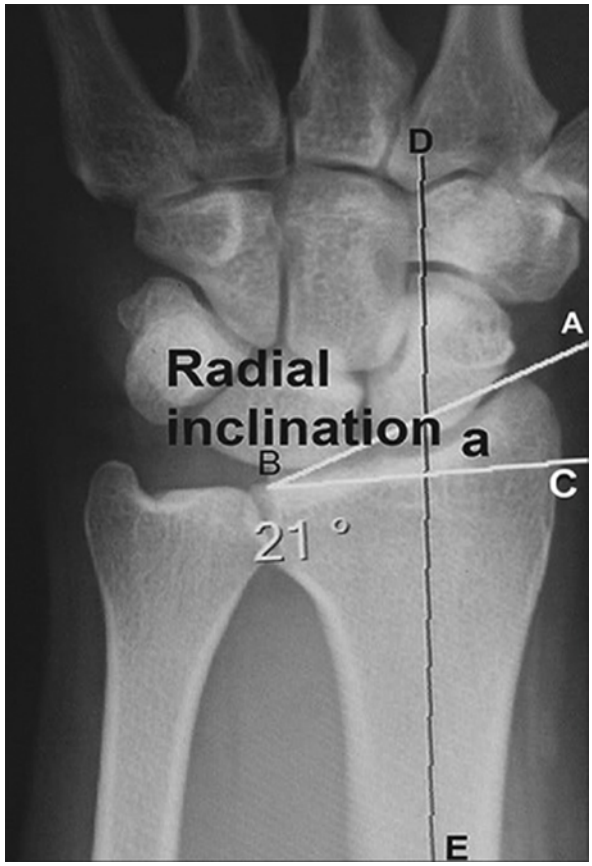

Figure 1: Radial inclination 'a' is the angle made by the tangential and the horizontal line drawn at the level of lunate fossa.

Palmar Tilt

Palmar tilt was measured on lateral radiographs by drawing a line connecting the dorsal and palmer edge (line A- B) of the articular surface of the DER, then a perpendicular line (line B- C) from the palmer edge of the articular surface to the long axis (Line D-E) at the level of radial styloid process of the radius (Figure 4). Thus, the subtended angle (<ABC=<b) is the angle of palmar tilt.

RESULTS

Two hundred radiographs were included for analysis under this study. The ratio of male gender to female gender was of 156 male (78%) to 44 female (22%) patients. The distribution between right and left hand was 96 left (16 female, 80 male) and 104 right (28 female, 76 male) hand radiographs.

The range of age of the patients was from 18 to 80 years with an average of 32.46 ± 14.80 (standard deviation [SD]) years.

The analytical results of the study in various perspectives are given in the Tables 1, 2 and 3. The average value (n=200) of radial inclination was 20.78 ° ± (SD) 3.45° [Range: 14.9-29.1°], palmar/volar tilt 10.99° ± (SD) 3.87° [Range: 1.8-18.6°], radial length/height 11.39 mm ± (SD) 1.97 mm [Range: 8.3-27.7 mm], and ulnar variance 0.90 mm ± (SD) 3.14 mm [Range: +0.70 to +3.70]. These are tabulated in Table 1.

The values (average ± SD) of the radial inclination 21.07 ± 3.53°, palmar/volar tilt 11.10 ± 3.78°, radial length/height 11.66 ± 2.02 mm, and ulnar variance was 0.96 ± 3.72 mm for the male gender. And the corresponding values for the female gender were radial inclination 19.74 ± 3.08°, palmar/volar tilt 10.64 ± 4.36°, radial length/height 10.43 ± 1.52 mm, and ulnar variance was 0.70 ± 2.52 mm [Table 2]. Even then, there was no statistical significance in the differences of the morphometrical parameters.

Morphometrical parameter measurement for the right hand had the values of (average ± SD) radial inclination 19.76 ± 3.60°, palmar/volar tilt 9.24 ± 4.28°, radial length/height 11.24 ± 2.08 mm, and ulnar variance 0.92 ± 3.74 mm. Further, the corresponding morphometrical measurement for the left hand had the values of (average ± SD) radial inclination 21.89 ± 2.97°, palmar/volar tilt 12.89 ± 2.22°, radial length/height 11.55 ± 1.87 mm, and

Figure 2: Radial height is the distance measured from the level of lunate fossa to the level of the styloid process of the radius.

Table 1: Distribution of radial inclination, palmar tilt, radial height, and ulnarvariance in n=200 subjects

Parameter	Mean±SD (range)
Radial inclination (°) (range)	20.7 8 ± 3.45 (14.9-29.1)
Palmar tilt (°) (range)	10.99 ± 3.87 (1.8-18.6)
Radial length (mm) (range)	11.39 ± 1.97 (8.3-27.7)
Ulnar variance (mm) (range)	0.90 ± 3.14 (+0.70-+3.70)

Table 2: Distribution of morphometric parameters (average±standard deviation) among the male and female gender

Parameter	Male	Female	P
Radial inclination (°)	21.07 ± 3.53	19.74 ± 3.08	>0.05
Palmar tilt (°)	11.10 ± 3.78	10.64 ± 4.36	>0.05
Radial length (mm)	11.66 ± 2.02	10.43 ± 1.52	>0.05
Ulnar variance (mm)	0.96 ± 3.72	0.70 ± 2.52	>0.05

Table 3: Distribution of morphometric parameters (average±standard deviation) among the right and left side radiographs

Parameter	Male	Female	P
Radial inclination (°)	19.76 ± 3.60	21.89 ± 2.97	>0.05
Palmar tilt (°)	9.24 ± 4.28	12.89 ± 2.22	>0.05
Radial length (mm)	11.24 ± 2.08	11.55 ± 1.87	>0.05
Ulnar variance (mm)	0.92 ± 3.74	0.89 ± 2.64	>0.05

Figure 3: Ulnar variance is the distance calculated between the two horizontal lines drawn perpendicular to the axis of the radius and ulna at the distal cortical margin.

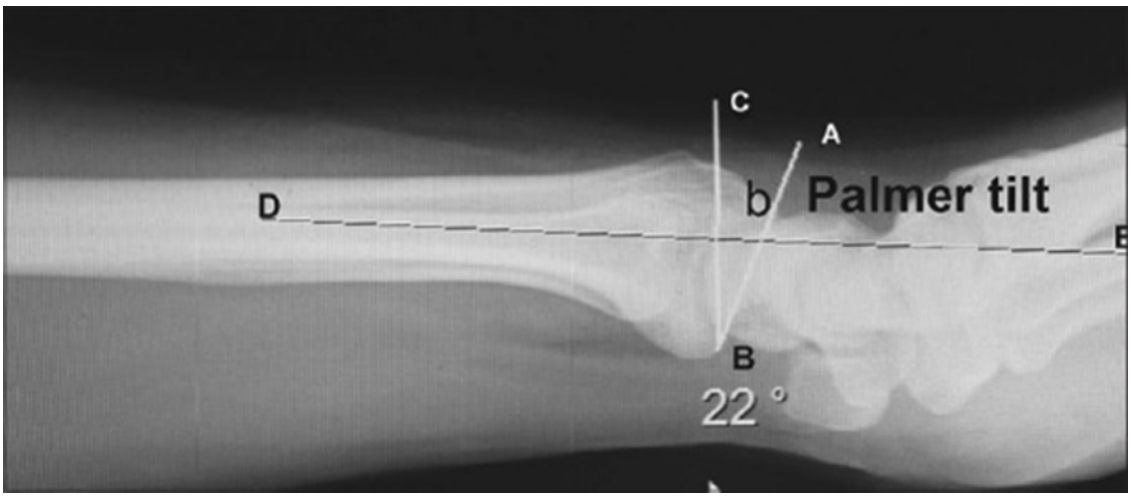

Figure 4: Palmar tilt is the angle formed by the meeting point of the two lines, one tangential line to the articular surface of the distal end radius and the second perpendicular line at the level of styloid process.

Table 4: Comparison between our study and other previously reported studies

Morphometrical parameters of the DER reported in various study reports					
Morphometric parameters of the distal end radius	1) Our study	2) (Mishra *et al.*, 2016) (Indian race)	3) (Gupta *et al.*, 2015) (Indian cadaveric study)	4) (Prithishkumar *et al.*, 2012) (Indian cadaveric study)	5) (Chan *et al.*, 2008) (Indian race)
Radial inclination (°)	20.7 8 ± 3.45	23.27±7.42	Total: 25.05 Left side: 24.0 Right side: 25.6	Left side: 21.8±2.5 Right side: 22.1±2.9	27±3.18
Palmer tilt (°)	10.99 ± 3.87	10.07±5.28	Not reported	Left side: 8.2±2.9 Right side: 9.1±2.0 (P=0.05)	13±3.57
Radial height (mm)	11.39 ± 1.97	11.31±4.9	Left side: 10±0.13 Right side: 9.7±0.14	Left side: 11±1.4 Right side: 10.8±1.5	Not reported
Ulnar variance (mm)	0.90 ± 3.14	0.66±2.46	Not reported	Not reported	0.13±0.70
Morphometrical parameters of the DER reported in various study report					
Morphometric parameters of the distal end radius	1) (Schuind *et al.*, 1992)	2) (Werner *et al.*, 1992) (cadaveric study)	3) (Altissimi *et al.*, 1986)	4) (Gartland and Werley, 1951)	
Radial inclination (°)	24 (19-29)	30	16-28	23 (13-30)	
Palmer tilt (°)	Not reported	6	0-18	11 (1-21)	
Radial height (mm)	Not reported	Not reported	Not reported	Not reported	
Ulnar variance (mm)	-4.2-+2.3	-40.1-1.4	-2.5-+3.1	Not reported	

Table 5: Comparison between our study and the reference value of Orthopaedic Trauma Association

Parameter	Our study	OTA reference value
Radial inclination (°)	20.7 8 ± 3.45 (14.9-29.1)	13-30
Palmar tilt (°)	10.99 ± 3.87 (1.8-18.6)	1-21
Radial length (mm)	11.39 ± 1.97 (8.3-27.7)	11-13
Ulnar variance (mm)	0.90 ± 3.14 (+0.70-+3.70)	Neutral

ulnar variance 0.89 $\pm$ 2.64 mm, respectively. Furthermore, there was absence of any differences that were statistically significant among the measurement of the morphometrical parameters.

DISCUSSION

The standard values to treat the injuries of the distal end of the radius bone in the clinical practice, orthopaedic surgeons are following the reliable reference values of Gartland and Werley as the standard one (Gartland and Werley, 1951). But, the research article throws light on the radiographical study on the morphometrical parameter measurement of the DER of the country's general population. It is pretty sure that all the anatomical structures vary among the different races all over the world. Hence, the morphometrical parameters too have changes among the distinct races. Therefore, this makes it necessary for the evaluation of the morphometrical parameters among specific races prevalent in the various parts of a country individually. Since there are no available data for utilization, the orthopaedists need to depend on the only available Western data comprising the measurement of the morphometric parameters of the DER. Literature has brought out the statistically significant (variable) differences in the ulnar variance among the Chinese and the Malaysian races by the study done by (Chan *et al.*, 2008) of the Malaysian population (Chan *et al.*, 2008; Hadi and Wijiono, 2013).

Few authors do not support the idea of using the radiographs as a tool for evaluation of the measurement morphometrical parameters of the DER. The influence of rotation on the palmar/volar tilt is shown in the cadaveric study done by Johnson and Sazbo. The 1.6° alteration of the palmar/volar tilt is due the 5° rotation in the lateral view of the radiograph. In further study by (Pennock *et al.*, 2005) there is alteration in the morphometrical measurement of the radial inclination, radial length/height and the palmar/volar tilt. It is seen that there is significant increase in the morphometrical measurements due to supination and also the apparent decrease in the morphometrical measurements due to pronation is observed significantly (Johnson and Szabo, 1993; Pennock *et al.*, 2005).

As our study was carried out prospectively, while obtaining the radiograph of the patients, we tried to maintain the forearm in the neutral position to overcome the alterations in the morphometric parameters of the DER due to pronation and supination, during the positioning of the hand. Since the cadaveric population is generally elder than the normal living population seeking clinical management in a hospital setup, wherein our study group has homogeneous distribution of age. This contributes to the superiority of our study. Due to the reason of lack of history about the cadaver, there are high chances of including a pathologic bone into the study group. Other factor contributing to the drawback in the cadaveric study is the methodology of the conversion of the cadaveric (osteometric) morphometric parameters measurement value to the values required for the management in the clinical practice where the morphometric measurement is done entirely dependent upon the radiographs. We can also observe that the assessment of reduction of the fracture of the forearm in the DER is mainly by the restoration of the angle of radial inclination and the palmar/volar tilt which is done by radiological methods.

The literature works have clearly proven the indirect relationship between the restoration of the morphometrical parameters of the DER and the post fracture reduction functional after effect along with the wrist joint's biomechanics. About twenty cadavers with artificially made dorsal angulation in the wrist joint was studied by (Miyake *et al.*, 1994) and established the shift of the stress concentration in the regions of the wrist joint. It is seen that in dorsal angulation of the wrist joint, the stress is concentrated on the dorsal aspect of the radiolunate joint. While the force is concentrated upon the volar regions of the radiolunate joint when the wrist joint is in the neutral position (Miyake *et al.*, 1994). An almost similar result was found by Pogue in their study on malunion of the wrist joint mechanics (Pogue *et al.*, 1990). The increase in the force transmitted through the ulna bone of the forearm caused due to the dorsal angulation and related transfer in the concentration of the force in the region of the wrist joint was brought out by the study done by (Short *et al.*, 1987). Almost about 50% weight bearing by the ulna bone is contributed by 30 degrees of dorsal angulation. This establishes the fact that dorsal angulation of the wrist joint results in increase of the force transmitted through the ulna bone (Short *et al.*, 1987).

Kienbock's disease, a prevalent condition among the white races has liability with negative values of ulnar variance parameter in the wrist joint. In the study conducted by (Gelberman *et al.*, 1975) the data was statistically significant to prove the aetiology of the disease was established (Gelberman *et al.*, 1975). In the study have shown the correlation of the morphometric parameter ulnar variance. Its negative value is associated with scapho-lunate dissociation, avascular necrosis of the lunate bone, avascular necrosis of the scaphoid bone of the hand (Smet and L, 1994).

On the other hand, degeneration on the cartilage of the carpal bone due to increased abundant loading over the ulnar compartment causing triangular fibrocartilage complex (TFCC) degeneration is contributed by the positive value of the ulnar variance. The most disturbing cause for alterations in the kinematics around the wrist joint is the TFCC causing shortening of the radius bone. This was established by Adams in the research laboratory. The similar and milder contribution is given by the morphometric parameter of radial inclination (Adams, 1993).

The proportion of the fracture occurring in the region of the distal end of the radius bone around the wrist joint among the fractures of the upper limb has a prevalence of 8-15% (Nana *et al.*, 2005; Austin and Veillette, 2009). The knowledge about the morphometrical parameters of the DER is very much essential for the management of the injuries occurring in the wrist joint. This proves the importance of the morphometrical study involving the DER for evaluating the patients and the clinical management of the fracture of the wrist joint. The anatomical alignment can be achieved only with the help of standard data available for the normal values of the morphometrical parameters of the DER (Sandjaja, 1993).

The single observer study with smaller population done at only one hospital is the limitations of this study. The comparison of the morphometrical parameters' values may be altered due to unequal gender distribution. But, the side distribution (left and right wrist joint) is well maintained in our study. Multiple observers are required for the homogeneity of the results in the further observational studies. The comparison of the left and right side morphometrical parameters in our study gives an added advantage to avoid the individual differences in the parameters and uniqueness of the development of each single individual. Certain schools of thought accept only the contra lateral wrist as the reference value for the best clinical management of the individual and deny the usage of the standardized values of different races as the reference for the morphometrical parameters. For example, (Hollevoet, 2000) compared the variability of the differences in the right-left sides with the variability of the entire study group. For the morphometrical parameters radial inclination, ulnar variance and palmar/volar tilt, the statistical differences were significantly less. This proves that the contra lateral wrist is the best reference value for the management of the injuries in the DER of an individual rather than the standard reference value available for the general population (Hollevoet, 2000).

The comparison of the data of the morphometrical parameters between our study and the previously reported studies has been tabulated in the Table 4. The largest value for radial length/height and palmar/volar tilt is seen in the study conducted by (Werner *et al.*, 1992) for the morphometrical parameters of the wrist joint involving the DER (Werner *et al.*, 1992). Since the morphometrical parameters vary widely among the different ethnic races all over the world, it holds an important reason to follow separate reference values of the morphometrical measurements of the parameters of the DER for the clinical management of the fracture of the wrist joint. This has been well-established in Table 5.

All the four morphometrical parameters namely the radial inclination, radial length/height, palmar/volar tilt and the ulnar variance gave similar results with the study conducted by (Mishra *et al.*, 2016) among the Indian population. This establishes the uniformity among the anatomical alignment of the Indian race. Further study in the area will help in standardizing the normal values and the reference data can be developed for the Indian race that will help in the clinical management of the injuries to the wrist joint.

The radial inclination in our study has the value of 20.78° lies near to the criteria followed by the Orthopaedic trauma association that is the most widely accepted and followed criteria for the clinical management for the injury around the wrist joint. This shows similar results with the previous studies conducted by (Schuind *et al.*, 1992; Altissimi *et al.*, 1986).

CONCLUSIONS

There is necessity for further researches in the analysis of the morphometrical parameters of the distal end of radius bone in the Indian population. For the clinical management of the injuries around the wrist joint the results of this study can be used as a reference standard to anatomically align the bones and the affected structures. The most important requirement in the clinical management of the fracture of the wrist joint is the unique standard distribution of the morphometrical parameters of the DER among the different races of the Indian population for providing the best treatment to the patients. Further, researches must be done involving a larger study group with homogenous distribution of age and gender, performed upon distinct races of the general population and comparing the morphometrical parameters obtained from the cadavers with the radiographs of the Indian population.

Conflict of Interest

The authors declare that they have no conflict of interest for this study.

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