The association between Radiological indices and functional outcomes in distal radius fracture

Abstract

Introduction: One of the factors affecting the prognosis of distal radius fracture is the anatomical correction. Studies relating anatomical reconstruction with functional consequences have had conflicting results. This study is aimed to investigate the relationship between radiographic indices (anatomical) after displaced distal radius fractures with function and clinical outcomes.

Methods: In a retrospective cohort study, radiographic indices, including the radius, volar tilt, teardrop angle, articular cavity depth, and AP Distance were investigated. Pinch and grip strength were measured and the Quick DASH questionnaire evaluated the performance.

Results: Pain score significantly correlated with radial shortening (P=0,038), but it was not independent of treatment method. Patients' satisfaction rate was significantly lower in patients with abnormal articular depth, independent of age and treatment method (P=0.004). Quick-DASH score significantly correlated with radial shortening and articular cavity depth, independent of treatment method and age (P=0.006). Percutaneous pinning was associated significantly with less pain, less disability, and more satisfaction (P<0.05).

Conclusion: Radial shortening and articular cavity depth were correlated with clinical and functional outcomes. While Some studies suggest that radiographic indices in the elderly are not necessarily correlated with functional outcomes, in this study correlation of radiologic indices with clinical and functional outcomes was independent of age.

Keywords: Distal radius fracture, radiological index, clinical outcomes, functional outcome

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Introduction

Distal Radial fracture is one of the most common fractures, responsible for approximately 17% of all detected fractures[1]. It affects both genders and is mostly seen in children aged 5 to 14 years, men under 50, and women over 40 [2]. Two-thirds of these fractures are associated with displacement and require anatomical correction[3]. Diagnostic Radiographic signs of displaced fractures are radial shortening, as well as the displacement of the distal end dorsally (dorsal tilt) or ventrally (volar tilt). Radiographic views include simple antro-posterior, lateral and oblique views in extra-articular fractures, as well as the use of CT-scan in intra-articular fractures. The treatment depends on the type of fracture and the general condition of the patient includes conservative and surgery. Several therapeutic methods have been introduced[5]. Elderly people with low activity level and high risk for surgery who have a stable fracture are usually managed conservatively. In other cases, a variety of surgical procedures are used, such as open reduction and internal fixation (ORIF)[6], percutaneous pinning and plaster [7,8], or using an external fixator. Each of these methods has favorable and undesirable outcomes. Good long-term consequences depend on many factors, such as patient-related factors, the severity of injury, fracture pattern, and type of treatment. The first three factors cannot be changed by the surgeon, so the consequences may not be similar in all patients[9]. Treatment should help to achieve normal or near-normal anatomy, and thus to achieve proper radiological patterns[10], and to prevent the patient's disability.

Various studies have been carried out on the anatomical reconstruction and functional consequences that led to contradictory results. Schneider and colleagues found that radial tilt and radial inclination had no direct effect on functional outcomes [11]. However, radial shortening and displacement at the joint level have been associated with adverse functional outcomes. In a study in Spain, researchers have shown that volar and Radial angles are critical determinants of patients satisfaction [12]. However, in a study of patients over the age of 70, functional outcomes in non-surgically treated patients with unfavorable radiographic indices (including tilt dorsal, radial tilt, and radial shortening) did not differ significantly in comparison with patients treated surgically with ORIF (anatomical outcomes being more favorable). Also, the group treated with conservative treatment reported less pain [13]. In another study, the acceptable consequences of anatomical reduction, including dorsal and volar tilt, were not significantly correlated with better physical and psychological outcomes, higher DASH score, and satisfaction of patients [14].

Regarding the contradictory results in previous studies, and also not considering all radiological indices in previous studies, we decided to investigate the association of radiographic indices after treatment of displaced fracture of distal radius with clinical and functional outcomes of patients.

Methods

In a retrospective study, the association between radiographic indices with clinical and functional outcomes in distal radial fractures was evaluated. The study population consisted of patients with displaced distal radius fracture with non-surgical treatment (close reduction and casting), percutaneous pinning and plaster, and external fixation. Wrist immobilization was 6 to 8 weeks for all patients (depend on evidence of radiologic healing) and physiotherapy was prescribed for all patients after the immobilization period. The study was conducted from April 2016 to March 2017 in the orthopedic department of Imam Khomeini Hospital in Sari, Iran. The study was approved by the ethical committee of Mazandaran University of medical sciences (*IR.MAZUMS.IMAMHOSPITAL.REC.952814*).

Inclusion criteria: Patients with age over 18 years, displaced extra-articular or simple intra-articular fracture (AO classification types 23-A2, A3, B1, B2 , C1, and C2), an isolated injury, were enrolled in the study. 9 months' minimum follow-up period was considered.

Exclusion criteria: Multiple traumas, a complex intra-articular fracture requiring ORIF, open fractures, fractures with vascular damage, wrist instability, bilateral lesions, and inflammatory arthritis, were excluded.

Measurement

According to patients' files, 77 patients were enrolled in the hospital archives based on inclusion and exclusion criteria. The patients were contacted and invited to attend the study. Sixty-four of them accepted and after obtaining written consent, they were enrolled in the study. The demographic data of patients including age and sex were recorded. The range of motion of the wrist (ROM) including flexion, extension, supination, pronation, radial deviation, and ulnar deviation were evaluated using a standard goniometer by an orthopedic resident. Any reduction in normal values (obtained from the healthy side) of the wrist range of motion is considered as a range of motion limitation Pinch and grip power were also evaluated by an orthopedic resident in a standardized manner using a dynamometer (Jamar Hydraulic Hand Dynamometer (200 lbs.) and Jamar (45 lbs.) Hydraulic Pinch Gauge). Patients' satisfaction from the treatment was evaluated based on the happy face-sad face score of 0 (maximum satisfaction) to 5 (dissatisfaction) and recorded for each patient. The pain in the wrist area was also assessed using the VAS criteria, scoring from 0 (painless) to 10 (most pain possible). A disability questionnaire, Quick Disabilities of Shoulder, Elbow, and Hand (Quick DASH), was also completed by patients. The questionnaire consists of 11 items, each of which contains 5 responses, from 0 (*performing without problems*) to 100 (*inability-the most severe symptoms*).

Radiological outcomes including inclination, volar tilt, dorsal tilt, tear angle, articular cavity depth, AP distance were evaluated by a radiologist who trained in musculoskeletal imaging, blind to clinical outcomes, using simple digital radiography in imaging system software of Imam Khomeini Hospital. Radiography was evaluated in two posteroanterior and lateral aspects. Radial Hight is the distance between two lines which drawn perpendicular to the long axis of the radius, one at the tip of the radial styloid and the second at the ulnar border of the distal radial articular surface(figure 1). This length is normally approximately 12 mm[4]. Radial shortening of more than 2 mm reduces the strength and radial shortening of more than 4 mm resulting in a significant decrease in strength and increased pain, so these were considered inappropriate. The radial inclination is the angle between a line perpendicular to the central axis of the radius and a line connecting the radial and ulnar limits of the articular surface of the distal radius (figure 2)and is approximately 23° (range, 13–30°) .Radial tilt is defined by the angle between the line drawn perpendicular to the central axis of the radius and the line that connects Dorsal and Palmar margin of the distal radius joint(figure 2). Normal volar tilt is approximately 11°[4,11]. A dorsal tilt of less than 10 degrees and a volar tilt of less than 20 degrees was considered acceptable[14,15]. The tear-drop (TDA) angle is also determined with the angle between the central axis of the radius shaft and the central axis of the teardrop (Figure 3). A normal teardrop angle is approximately 70°[4,11].

Statistical Analysis:

The data was submitted in the SPSS 22.2 Windows version. The mean and standard deviation were used to describe the parametric data and the frequency table for describing nonparametric data. Student's t-test was used for quantitative data analysis and X^2 test for analyzing qualitative data in two treatment groups. Pearson correlation coefficient and Chi-square test were used to evaluate radiographic, clinical, and functional outcomes. Univariate analysis was also used to evaluate the independency of the radiographic factor effects on clinical and functional outcomes. a P-value of less than 0.05 was considered a statistically significant level.

Results

Out of 64 patients studied, 26 were male (40.6%) and the mean age of the patients was 49.66 ± 16.62 years. The most common type of treatment was percutaneous pinning and plaster patients which were performed for 50 patients (78.1%). Eight patients (12.5%) underwent surgical treatment and external fixation, and 6 patients (9.4%) got conservative

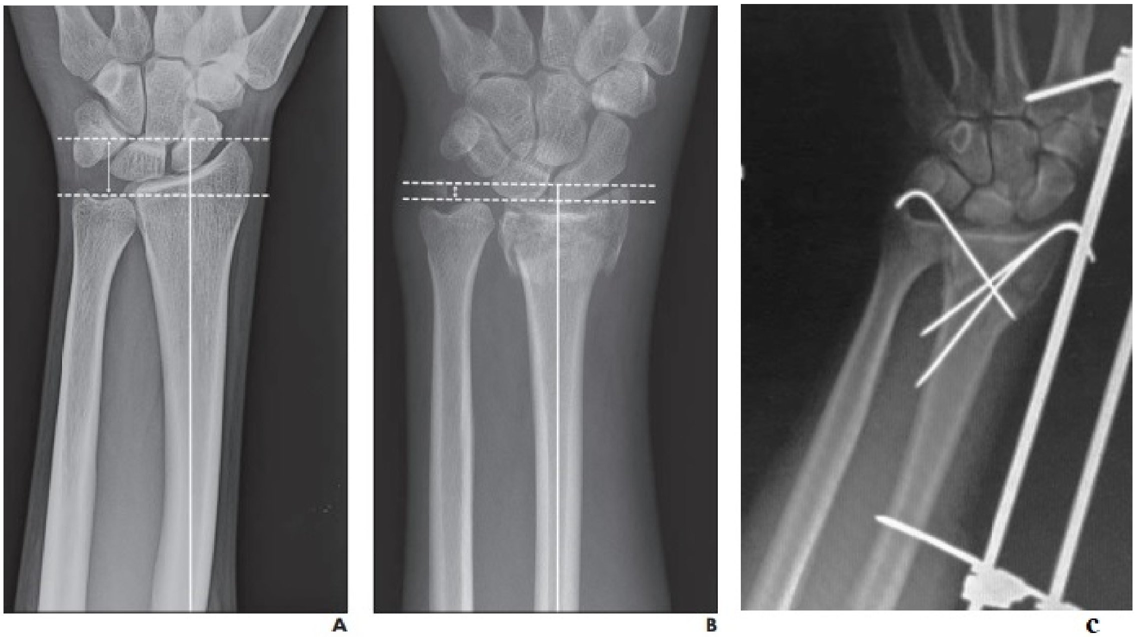

Figure 1: normal radial height (A), radial shortening (B) and after surgery (C)

treatment (closed reduction and plastering). The decision on type of treatment was made based on the surgeon's opinion and patient's general condition. Major complications of surgery were reported as neuropathy in only one patient (1.6%) and minor complications occurred in 4 patients (6.3%) including 4 superficial infections.

Pain: The mean score of pain was significantly lower in the pinning and plaster treatment than other treatments (P = 0.009). The mean score of pain was associated with radial shortening. Abnormal radial shortening was associated with greater pain, P = 0.038. This relationship has not been independent of the type of treatment and other indicators. The pain was not significantly correlated with other radiological indices.

Satisfaction: Satisfaction with the pinning and plaster method was significantly higher than other treatments, P = 0.008. The satisfaction rate was significantly lower in patients with abnormal articular depth, which was independent of age, other radiological indices, and type of treatment, P = 0.004. Satisfaction was not correlated with other radiological indices.

Quick-DASH Score: The Quick-DASH scores were significantly lower in Pinning and plaster treatment than the other treatment methods, P = 0.003. The Quick - DASH score in patients with abnormal radial shortening and abnormal articular cavity depth was higher in comparison with normal values, and its correlation was independent of age, other radiological indices, and type of treatment, P = 0.006. The quick-DASH score did not have a significant correlation with other radiological indices.

Grip and Pinch strength: Grip and Pinch strength was not associated with radiological indices after treatment.

Range of Motion Restrictions: The flexion limitation was independently associated with the depth of the articular cavity. Other ranges of motion were not significantly correlated with radiological indices.

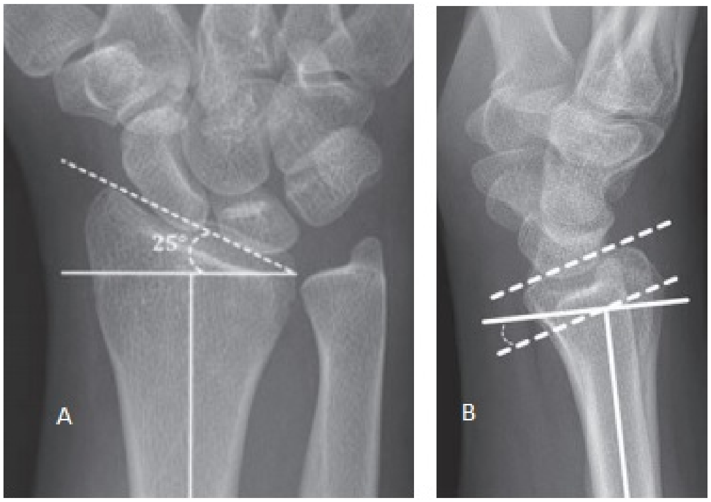

Figure 2: Radial inclination(A) and volar tilt(B)

Figure 3: tear-drop angle

Radiographic indices: the mean (SD) of radial length was 11.7(1.89) in close reduction and casting group, 9.80(3.85) in pin and plaster group and 12.66(0.51) in external fixation group(p=0.056). For radial inclination these values were respectively 23.42(2.92), 20.43(3.55) and 22.33(5.16)(p=0.06).the mean(SD) of TDA were respectively 67.07(1.63)66.64(11.61) and 48.66(19.62)(P=0.9). there were no significant difference in volar/dorsal tilt between groups.

In the quantitative analysis, based on Pearson correlation coefficient, an inverse relationship between tear-drop angle and satisfaction (r = -0.23, P = 0.06), pain intensity (r = -0.08, p = 0.50) and quick-DASH score (r = -0.25, P = 0.84) were observed, even though it was not statistically significant. Also, there was no significant relationship between this angle and grip strength (r = -0.07, P = 0.23 and pinch strength (r = -0.23, P = 0.34). Radial Anterior-posterior (AP) distance was in normal range in all patients, therefore its relationship with clinical and functional outcomes could not be evaluated. (table1)

Patients' age was not significantly correlated with satisfaction, severity and score of quick-DASH (r = 0.18, P = 0.14, r = 18, P = 0.12, r = 0.17, P = 0.17, respectively). Major and minor complications were not significantly different between treatment methods, P=0.67. (table2)

Table 1- Complications difference between treatment methods

Treatment method Complication	Conservative	Percutaneous pinning	External fixation
Major no(%)	1 (0.0)	1 (2.0)	0 (0.0)
Minor no(%)	1 (16.7)	2 (4.0)	1 (12.5)
X2=2.31, P=0.67			

Discussion

Distal Radius fracture is one of the most common fractures referred to orthopedic clinics and emergency rooms[16]. Decreased bone density, female sex, race, heredity, premature menopause are the risk factors for this type of fracture. The long-term desirable consequences of this type of fracture depend on several factors such as patient-related factors (age, sex, bone density, etc.), the severity of injury, fracture pattern, and treatment methods. Of these, the first three factors are not modifiable by the surgeon, so clinical

outcomes may not be the same for all patients [16].
Treatment is usually based on restoring the anatomy to normal or near-normal levels based on radiographic indices. Several studies have suggested the association between favorable radiological indices, indicating the establishment of anatomy, with clinical outcomes [16,17]
In the present study, the association of radiographic indices after treatment with clinical and functional outcomes has been investigated. Radiographic indices include the presence of step off at the joint surface, the radial AP distance, the depth of the articular cavity, radial length, radial tilt, volar tilt, and teardrop angle, were determined. Among the evaluated indices, the depth of the abnormal cavity was significantly associated with decreasing patient satisfaction, and the abnormal ulnar deviation and radial shortening had a significant relationship with the increase in the score of Quick-Dash. Also, the presence of a step off and radial shortening associated with abnormal ulnar deviation. Pinch and handgrip strength, limitation of wrist movements, and severity of pain had no significant relationship with any radiological index. However, the treatment method has a significant relationship with the clinical outcomes of patients. Percutaneous pinning and plaster treatment was significantly associated with patient satisfaction, lower pain, and lower quick-DASH scores. In the external fixation method, the pain was greatest, the quick-DASH scores and satisfaction were lowest. In this study, the age of patients was not correlated with clinical and functional consequences. In Aradhana T and et al. study [18], the most favorable clinical outcomes were reported in younger patients. Also, in patients with a minimal displacement fracture and conservative treatment, the outcomes were better. Meanwhile, in this study, age was not associated with the optimal clinical outcomes, as well as percutaneous pinning approach associated with the desired outcomes. In the study of Aradhana T and et al. volar tilt, radial length, radial inclination, and the presence of step at the joint surface were evaluated, among which maintaining the inclination and radial length, and the absence of step at the joint surface were significantly correlated with the favorable outcomes. However, in the present study, only maintaining the depth of the articular cavity and radial length was associated with a favorable outcome. In a study by Erhart S and et al., It was shown that an increase in the depth of the articular cavity slightly contributed to significant impairment in the contact biomechanics of the radio-carpal joint and significantly reduced the range of joint movement. It can also lead to an increased risk of degenerative changes [19] and the greater compression of the radius head, the greater chance of post-trauma osteoarthritis. As a result, by restoring the normal distal radius shape, it is possible to minimize the risk of post-traumatic osteoarthritis in the radio-carpal joint [20].
In various studies, the association of radiographic indices such as volar tilt [21, 22], radial length [24-22], intra-articular step [25, 26] has been suggested as predictors of clinical outcomes. In the study of Schneider and et al., radial shortening and the presence of a step at the joint level, have been reported as the most important radiological indexes affecting clinical outcomes. However, Tafoya et al. [12], has reported Palmar tilt, was an index affecting clinical outcomes. Of course, it should be considered that all radiological indices were not studied in these studies. The results of these studies indicate in different studies various radiological

indices were reported related to clinical outcomes, and also in many studies, reports have shown that radiological indices are not associated with clinical outcomes [26-28]. In a study by Arora R et al.[13], researchers reported that undesirable radiological outcomes do not necessarily have associated with adverse clinical consequences. Elderly people were studied in this study, and non-surgical treatment was also better suited to these patients, with more favorable outcomes. in this study correlation of radiologic indices with clinical and functional outcomes was independent of age.

Limitations:

In the present study, the number of patients treated by external fixation method was low and the results of treatment in this method were not well evaluated. In this study, intra and extra-articular fractures were not evaluated separately

Conclusion

According to the findings of this study and other studies, radiographic indices that are related to articular surfaces such as the presence of step or the depth of the articular cavity as well as radial length can be effective on the clinical outcomes of the patients.

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Table 2- Association between radiological indices and clinical and functional outcomes

outcome	Intra-articular step		P-value	Radial shortening		P-value	Articular cavity depth		P-value	Radial inclination		P-value
	no	yes		Normal	Abnormal		Normal	abnormal		Normal	abnormal	
Pain [a]	2.13(1.92)	2.66(20.06)	0.52	2.00(1.96)	3.50(0.92)	**0.053**[*]	20.17(1.87)	3.00(2.39)	0.20	2.58(2.18)	1.81(1.59)	0.11
Satisfaction [b]	1 (1)	1 (1)	0.50	1(1)	1(0)	0.23	1(1)	2(2)	**0.004**[*]	1(1)	1(1)	0.43
Quick-Dash score[a]	18.14(15.67)	27.26(17.72)	0.18	16.92(15.80)	35.52(7.15)	**0.006**[*]	17.08(15.59)	32.37(12.07)	**0.006**[*]	21.17(19.14)	16.94(12.17)	0.29
Grip strength [a] Uninjured/injured	0.81 (0.23)	0.96 (0.04)	0.30	0.82(0.24)	0.87(0.13)	0.47	0.85(0.22)	0.72(0.21)	0.067	0.76(0.21)	0.85(0.21)	0.25
Pinch strength Uninjured/injured	0.96 (0.13)	1.01 (0.01)	0.70	0.96(0.26)	1.00(0.08)	0.33	1.11(0.26)	1.00(0.26)	0.21	0.93(0.25)	0.91(0.15)	0.45
Flexion limitation*	26 (96.6)	6 (100)	1.0	54(96.4)	8(100)	1.0	56(100)	6(75)	**0.001**[*]	31(100)	31(93.9)	0.49
Extension limitation*	38 (65.5)	6 (100)	0.16	38(67.9)	6(75.0)	0.68	38(67.9)	6(75)	1.0	23(74.2)	21(63.6)	0.42
Supination limitation*	8 (13.8)	2 (33.3)	0.23	8(14.3)	2 (25.0)	0.60	8(14.3)	2(25.0)	0.60	10(16.7)	0(0.0)	1.0
Pronation limitation*	6 (10.3)	2 (33.3)	0.15	6(10.7)	2(25.0)	0.26	8(14.3)	0(0.0)	0.58	3(9.7)	7(21.2)	0.30
Abnormal ulnar deviation*	10 (17.2)	4 (66.7)	**0.001**[*]	4)66.7)	10(17.2)	**0.001**[*]	10(17.9)	4(50.0)	**0.04**[*]	8(25.8)	6(18.2)	0.55

[a] mean(SD); [b] median(SD); [c] no(%); * adjusted

*any reduction in NL values (obtained from healthy side) of wrist ROM is considered as a ROM limitation

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