Article

Journal of Orthopaedic Surgery

Journal of Orthopaedic Surgery
25(1) 1–6

DOI: 10.1177/2309499016684976
journals.sagepub.com/home/osj
SAGE

The relationship between radiological alignment of united distal radius fractures and functional and patient-perceived outcomes in elderly patients

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Abstract

Purpose: The purpose of this study was to investigate the relationship between radiological alignment and functional outcomes including strength, range of motion (ROM), and disabilities of the arm, shoulder, and hand (DASH) and patient-rated wrist evaluation (PRWE) scores in elderly patients with united distal radius fractures. **Methods:** We reviewed 118 patients (mean age of 76.2 $\pm$ 9.5 years, mean follow-up 36.3 $\pm$ 17.6 months). Outcome measures included the DASH and PRWE scores, ROM, and grip and pinch strength were measured using a validated mobile hand-held dynamometer. Radial height, radial inclination, ulnar variance, and palmar tilt were measured on standard radiographs. **Results:** The mean total score for DASH was 4.9 $\pm$ 7.4 and 6.9 $\pm$ 11 for the PRWE. There were significant differences in ROM for palmar flexion and ulnar deviation between the affected wrist and the normal wrist. Linear regression revealed significant relationships for the following variables: between DASH and radiological palmar tilt, between PRWE and radiological palmar tilt, between grip strength and radial inclination, between grip strength and radial height, and between grip strength and ulnar variance. **Conclusion:** This study suggests that minor deformities of the distal radius following distal radius fractures treated with either operative or nonoperative treatment are unlikely to be clinically relevant and have no impact on patient perceived outcomes for elderly patients.

Keywords

conservative treatment, distal radius fractures, elderly patients, operative treatment, radiological outcome, wrist function

Introduction

Fractures of the distal radius are common, accounting for approximately one sixth of all fractures seen in the emergency department.[1,2] They have a bimodal age distribution, and elderly individuals between 60 years and 69 years old have a higher incidence of injury. The treatment of these fractures remains controversial and ranges from closed reduction and cast immobilization to surgical intervention.[2,3–5] Intra-articular extension has been reported to occur in 50–81% of distal radius fractures, and closed reduction techniques do not restore intra-articular congruity.[6]

Clinical practice guidelines from the American Academy of Orthopedic Surgeons suggest the following criteria for reduction: restoration of radial length within 2–3 mm of the contralateral wrist, palmar tilt neutral or less, intra-articular step-off of less than 2 mm, and radial angle loss of less than 5°.[5] To date, orthopedic and trauma societies have still been unable to establish treatment guidelines for the elderly patient with a distal radius fracture. According

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to the 2010 American Academy of Orthopedic Surgery Clinical Practice Guideline Summary of Treatment of Distal Radius Fractures, no consensus was reached on the treatment of distal radius fractures in elderly patients.[5] Current controversies include acceptable fracture reduction and alignment, the treatment of osteoporotic fractures, surgical versus nonsurgical treatment, and preferred surgical technique. Moreover, no consensus currently exists regarding what constitutes a satisfactory functional outcome after distal radius fractures in older adults.[7]

The purpose of this study was to critically assess the outcomes of a series of united distal radius fractures in patients above the age of 60 years. The primary purpose was to investigate the relationship between radiologic alignment and subjective outcomes, as measured by the disabilities of the arm, shoulder, and hand (DASH) questionnaire and the patient-rated wrist evaluation (PRWE) score. The secondary purpose was to investigate the relationship between radiologic alignment and objective outcome measures including grip strength, pinch strength, and range of motion (ROM).

Methods

Patient identification and data collection

This research was conducted as a retrospective study; prior approval to conduct the study was granted by our institutions IRB. Participants who were treated for distal radius fractures (both intra-articular and extra-articular) between April 2003 and April 2009 were identified from our departmental database. The following inclusion criteria were applied: patients above the age of 60 years, treated at our hospital at least 12 months prior to enrolment, normal contralateral wrist with no history of injury or osteoarthritis, and able to give informed consent. Patients were excluded if they had a history of wrist fractures and had bilateral distal radius fractures, open fractures, compartment syndrome, dementia or other cognitive or psychiatric disorders, and polytrauma or multiple upper limb injuries.

Outcome measures

The subjective outcome measures consisted of the upper extremity specific DASH score[8] and the PRWE tool.[9]

ROM was evaluated using a standard goniometer with the elbow flexed to 90° and the wrist in pronation. For the evaluation of dorsiflexion and palmar flexion, radial deviation, and ulnar deviation, the method described by Armstrong et al. was used.[10] Forearm rotation (supination and pronation) was measured using the hand-held pencil method described by Karagiannopoulos et al.[11] All ROM measures were performed three times by one examiner; for analysis, the largest measured value was used.

Grip and pinch strengths were measured using a validated mobile hand-held dynamometer. The dynamometer consisted of a digital gauge with two exchangeable handles that were connected to an electronic unit. The apparatus measured the maximal isometric peak torque in Newton (N). Both grip and pinch strengths were tested three times in each hand by one examiner and averaged. For both ROM and strength, the contralateral limb was used as a control.

Standard radiographs including posteroanterior and lateral views, were taken for both wrists. All radiographs were digitized and imported into a software program for assessment (AutoCAD 2000®, Autodesk Inc, San Rafael, CA, USA). The following distal radius radiological indices (Figure 1) were measured three times using the method described by Cole et al.: radial height, radial inclination, ulnar variance, and palmar tilt.[12] The results of these three measures were averaged for analysis; similar to ROM and strength, the contralateral limb was used as a control.

Statistical analysis

A sample size calculation was performed based on the results of Jaremko et al.[13] Based on an alpha level of 0.05 and a power of 90%, 66 patients would be needed to achieve statistical significance.

The mean, standard deviation, and 95% confidence intervals of the demographic information, radiological alignment parameters, subjective outcome scores, and objective data were calculated. For comparison between the united distal radii fractures for radiological indices, ROM, and strength, the paired Student's *t*-test were used. To establish the relationship between radiological indices and patient-perceived subjective outcomes, a linear regression model with least squares estimation was chosen. Similarly, to establish the relationship between radiological alignment and the objective outcomes, strength, and ROM (independent variables), a linear regression model with least squares estimation was chosen. Normal data distribution was checked using the Shapiro–Wilks test. The lower two-sided 95% confidence interval was calculated for each correlation coefficient. A level of significance of $p < 0.05$ was selected. All analyses were conducted using STATA SE (version 12.0; StataCorp, College Station, Texas, USA) for Windows.

Results

One hundred eighteen patients with a mean age of 76.2 ± 9.5 years (range, 61–92) were included in this study. There were 21 males with a mean age of 76 ± 9.1 years (range, 61–99) and 97 females with a mean age of 76.8 ± 10.5 years (range, 60–94). There were 69 extra-articular and 49 intra-articular fractures. The mechanism of injury was a fall onto the outstretched hand in 114 patients, a motor vehicle accident in two patients, a fall from a bike in one patient, and recurrent falls in one subject. The mean duration of follow-up (calculated from the day of injury) was 36.3 ± 17.6 months (range, 12–76). Treatment modalities included

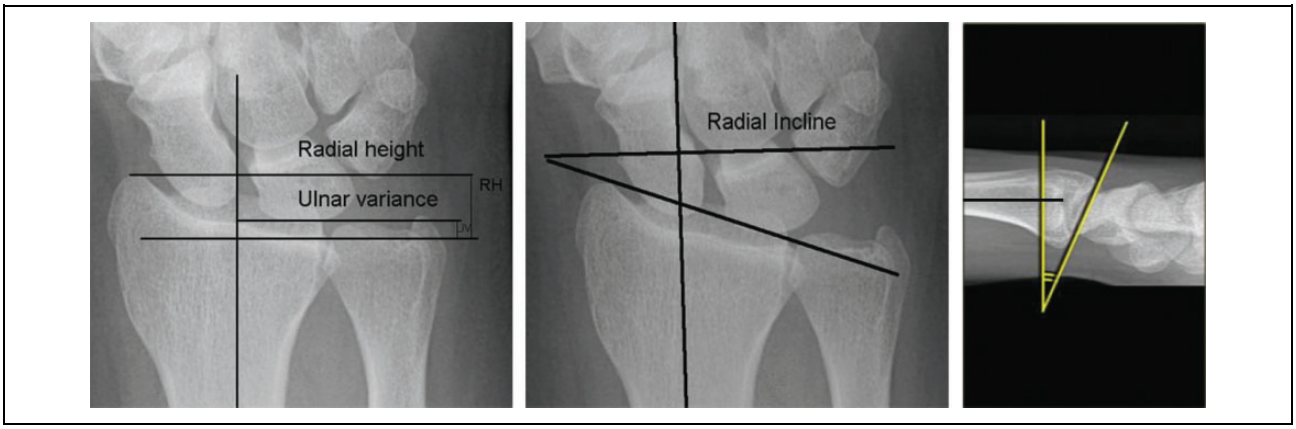

Figure 1. Standard radiographs, posteroanterior and lateral views were taken for both wrists. All radiographs were digitized and imported into a software program (AutoCAD 2000). The following distal radius radiological indices were measured three times: radial height, radial inclination, ulnar variance, and palmar tilt. The results of the three measures were averaged for analysis.

Table 1. Range of motion (in degrees) and grip and pinch strength (in newtons) of the normal wrist and affected wrist.

	Mean ± SD			
Objective outcomes	Affected wrist	Normal wrist	*p*	Four cases with poor results[a]
Palmar flexion	50.6 ± 16.4	57 ± 14.8	0.006	43
Dorsiflexion	58.9 ± 12.9	61.3 ± 12.9	0.2	46
Ulnar deviation	32.4 ± 7.2	35 ± 6.9	0.006	28
Radial deviation	30.9 ± 7.5	32.4 ± 7	0.2	23
Supination	87.7 ± 3.9	90 ± 0.5	0.1	82
Pronation	89.4 ± 2.6	89.9 ± 1	0.13	87
Grip strength	7.2 ± 2.1	7.6 ± 2.2	0.32	6.6
Pinch strength	3.3 ± 1.1	3.5 ± 1.1	0.28	2.4

DASH: disabilities of arm, shoulder, and hand; PRWE: patient-rated wrist evaluation.
[a]The mean results for the four cases with poor DASH and PRWE scores are listed for descriptive purposes only and were not compared to the remaining group with acceptable radiological alignment.

Table 2. Radiological indices of the normal and affected wrists.[a]

	Mean ± SD			
Radiological indices	Affected wrist	Normal wrist	*p*	Four cases with poor results[b]
Radial inclination (°)	20 ± 6.8	23 ± 3.8	0.003	10
Ulnar variance (mm)	−2 ± 2.8	0.6 ± 1.7	0.00001	+6.4
Radial height (mm)	10.9 ± 4.1	13.1 ± 2.2	0.001	6
Palmar tilt (°)	−2.7 ± 12.2	10 ± 3.7	0.00001	−36

DASH: disabilities of arm, shoulder, and hand; PRWE: patient-rated wrist evaluation.
[a]For ulnar variance: shorter than normal wrist; for palmar tilt: dorsal tilt.
[b]The mean results for the four cases four cases with poor DASH and PRWE scores are listed for descriptive purposes only and were not compared to the remaining group with acceptable radiological alignment.

closed reduction and casting ($n = 37$), close reduction and K-wires ($n = 32$), external fixation and K-wires ($n = 5$), and volar plate fixation ($n = 44$).

The mean total score for DASH was 4.9 ± 7.4 (range, 0–47.32). Only four patients (3.4%) had a DASH score above 25. The remaining 114 patients (96.6%) had DASH scores below 25. One hundred nine patients (92.4%) had DASH scores below 15. The mean total score for the PRWE was 6.9 ± 11 (range, 0–58). Only four patients (3.39%) had a PRWE score over 50. The remaining 114 patients (96.61%) had PRWE scores less than 50. One hundred four patients (88.14%) had PRWE scores less than 15.

ROM, grip strength, pinch strength, and radiological indices are summarized in Tables 1 and 2. There were significant differences in ROM for palmar flexion ($p = 0.006$) and ulnar deviation ($p = 0.006$) between the

affected wrist and the normal wrist. Significant differences between the affected wrist and the normal wrist were observed for all four radiological indices (Table 2). Linear regression revealed significant relationships for the following variables: between DASH and radiological palmar tilt ($r^2 = 0.23$, $p = 0.016$), between PRWE and radiological palmar tilt ($r^2 = 0.24$, $p = 0.012$), between grip strength and radial inclination ($r^2 = 0.42$, $p = 0.001$), between grip strength and radial height ($r^2 = 0.82$; $p = 0.001$), and between grip strength and ulnar variance ($r^2 = 0.61$; $p = 0.001$).

Discussion

The purpose of this study was to investigate the relationships between outcome measures and radiologic alignment in united distal radius fractures in patients more than 60 years old. While we were able to demonstrate significant relationships between DASH, PRWE, and radiologic palmar tilt, these correlations were only weak to moderate. This would suggest that loss of palmar tilt is only a weak predictor of patient-perceived outcomes and is therefore unlikely to be clinically relevant in the elderly. Descriptive analysis of the four patients with poor outcome demonstrated poor radiological alignment outside the recommended guidelines from the American Academy of Orthopedic Surgeons.[5] While these low numbers do not allow meaningful statistical analysis, it appears obvious that radiological malalignment has a strong influence on patient satisfaction and function.

Similar to our results, Finsen et al. demonstrated a statistically significant but weak correlation between four radiographic parameters and the PRWE and Q-DASH; the correlation coefficients were between 0.14 and 0.30.[14] The impact of the radiological parameters on the subjective outcome scores in their research is most likely clinically irrelevant, comparable to the findings of this study. Jaremko et al. evaluated the relationship between radiographic indices and subjective outcomes (DASH, SF-12, and satisfaction survey) in 79 patients over 50 years of age with distal radius fractures treated nonoperatively.[13] Patients with larger radiographic deformities had higher mean DASH scores (29.1) compared to the mean DASH scores (22.1) in those patients with acceptable alignment, suggesting slightly more disability in patients with radiographic deformities outside of the acceptable range. Grewal and MacDermid evaluated the relative risk of having a poor outcome across all age groups and clearly demonstrated the relationship between malalignment and functional outcome was not an "all-or-none" phenomenon.[15] Instead, outcome measures displayed a decreasing gradient of risk with advancing age; this gradient changes most significantly at the age of 60–65 years. Older patients were thus able to tolerate malalignment better than younger patients, perhaps reflecting differences in functional demands and expectations.

The findings of this study confirm the results of these previous reports, again suggesting that subjective patient perceived outcomes and radiographic alignment are not correlated in elderly patients. The radiologic alignment of all the cases in this study was well within the accepted limits recommended by the AAOS for the treatment of distal radius fractures; alignment variables outside these suggested parameters may have a significant effect on patient outcomes.[5] Presumably, most elderly patients place lower functional demands on the upper extremity.[6]

The secondary purpose of this study was to investigate the relationship between radiologic alignment and objective outcome measures, such as grip strength, pinch strength, and ROM. Radiologic alignment was not a predictor of ROM. In contrast, for three of the four radiologic variables (radial inclination, radial height, and ulnar variance), significant and strong relationships were observed for grip strength. This finding is somewhat surprising, given that there was no difference in strength between the normal wrist and the affected wrist. However, the grip strength of the affected wrist was only 2.5% less than on the normal side; this would clearly be of very limited, if any, clinical significance. In a previous study, Young and Rayan considered the loss of strength following distal radius fractures to be meaningful if the involved hand registered <60% that of the uninvolved hand.[16] Radial shortening, positive ulnar variance, and a decrease in radial inclination place the long flexor tendons at a mechanical disadvantage, often resulting in weaker peak grip force.[17] Despite the strong correlations, they identified, with only minor wrist deformities in our study, this effect was unimpressive and a relationship could not be established.

It has been suggested that grip strength ratios between the dominant hand and the nondominant hand follow the 10% rule.[18,19] However, most published studies are potentially underpowered, and current evidence may be insufficient to make judgments about grip strength impairment.[18] Armstrong and Oldham suggested that there is considerable variability in the relative strength of the two hands, and clinicians must be cautious when comparing strength measures between injured and uninjured hands.[20] In their study, they observed only small differences (0.1–3%) between the dominant and nondominant hands.[20] However, in patients recovering from distal radius fractures, grip strength was reduced to 50% of the uninjured side.[21,22] In our study cohort, the small differences in grip strength between the affected wrist and uninjured hand for 3 years after a distal radius fracture therefore simply suggest a return to normal. In contrast to grip strength, pinch grip involves more distal joints and intrinsic hand muscles. This is less likely to be affected by changes in wrist alignment or shortening and perhaps explains why pinch strength was not affected in the current study.

It appears obvious that displacement in excess of the recommended alignment is needed to notice a difference in clinical outcome. For example, Egol et al. retrospectively compared the outcomes for patients over the age of 65 years in whom displaced distal radial fractures were treated

operatively with plate fixation or external fixation (44 patients) or nonoperatively with cast immobilization (46 patients).[23] Radiographic outcome was superior for the patients in the operative group at each follow-up interval, and at 1 year, grip strength was significantly increased in the operative group. Similarly, Lee et al. demonstrated better results in patients treated with volar plating compared to percutaneous K-wire fixation (PKF). Increased dorsal radiological tilt was observed in the PKF group resulting in inferior functional outcome.[24]

In contrast, Young and Rayan reported that there was no significant correlation between radiographic and functional outcomes in 25 sedentary low demand patients older than 60 years (mean, 72 years) with displaced distal radius fractures.[16] Mean grip strength at the follow-up examination was 84% that of the unaffected side. Only two of their 22 patients (9%) with satisfactory functional outcomes had significantly decreased grip strength. Diaz-Garcia et al. performed a systematic review of 21 studies on the management of unstable distal radius fractures in patients over 60 and evaluated five common treatment modalities: volar locking plates, nonbridging external fixation, bridging external fixation, PKF, and cast immobilization.[2] There were significant differences in two radiographic parameters: volar tilt and ulnar variance. There were no clinically significant differences among the five treatment methods as measured by DASH, ROM, or grip strength. Zehir et al. compared Sonoma Wrx®, Sonoma Orthopaedic Products Inc, Buffalo Grove, IL, USA device to volar plating and did not find significant between group differences in a group of middle aged patients confirming that acceptable radiological fracture reduction as suggested by the American Academy of Orthopedic Surgeons results in satisfactory functional outcome.[5,25] Similar to our findings, the aforementioned studies could not demonstrate relationships between radiographic alignment and either ROM or pinch strength.[2,16,23]

In our series, there were four cases that clearly demonstrated an inferior clinical outcome. These four patients all exhibited unacceptable radiological alignment, with reduced radial inclination and radial length, substantial dorsiflexion, and positive ulnar variance. These radiological deviations from normal resulted in reduced ROM in all planes and reduced grip strength when compared to the remaining study cohort. Their mean DASH score was 33 and their mean PRWE score was 57, indicating that significant disability was associated with the residual deformity. While the small sample size does not allow valid statistical comparisons, these findings suggest that reduction as close to normal anatomic alignment as possible is important in the treatment of distal radius fractures in the elderly. Surgical treatment should be considered if nonoperative management cannot achieve acceptable radiological alignment.

The major strength of this project is the large sample size and an a-priori sample size calculation. It is therefore unlikely that a type II error was committed. Further merits of the current study include the length of follow-up (1 year or more post injury) and the use of validated, reliable, and responsive outcome measures (DASH and PRWE). Treatment was not randomized, and more severely displaced fractures were almost certainly managed with open reduction and internal fixation; less dramatic injuries were almost certainly more likely to have been treated with closed reduction methods. However, it is vitally important to recognize that this study was conducted independent of the treatment method. The relative benefits of operative and nonoperative treatment were not evaluated here and as such cannot be compared based on our data. This study has been specifically restricted to an assessment of the radiologic alignment of healed distal radius fractures in the elderly and its possible relationship to selected clinical outcome measures.

This study has several limitations, and patient-perceived outcome assessment scores can be affected by different factors. Guyatt et al. suggested two basic instruments for the quality-of-life measurement: generic instruments that provide a summary of health-related quality of life and specific instruments that focus on problems associated with single disease states, patient groups, or areas of function.[26] As a consequence, the current project did not evaluate the impact of the wrist fracture on the individual's mental and general health.[27] Instead, the current research project used instruments specific to the upper extremity (DASH) and to the wrist (PRWE) for subjective evaluation. However, Angst et al. has shown the SF-36 physical component summary and the DASH correlate highly ($r = 0.76$) and, in factor analysis, loaded on the factor "physical unspecific."[28] The DASH score therefore also acts as a generic instrument, replacing the mental and general health questionnaires.

Another limitation is the variability in the measurement of ROM. To reduce variability, all ROM measurements were made by a single examiner following a standard protocol using a goniometer. Edgar et al. have demonstrated that the use of a goniometer is accurate, reliable, and valid when applied using a standardized protocol.[29] To improve inter- and intra-rater reliability in the measurement of wrist ROM (flexion extension, radial deviation, and ulnar deviation), the goniometer was placed on the dorsal surface of the wrist, as advised by the American Society for Hand Therapists.[30] Finally, this study included both intra- and extra-articular fractures, and this could have resulted in bias. However, the overall aim of this project was to investigate the relationship between clinical and radiological outcomes. Any differences in radiological outcomes between these two fracture types should have resulted in different clinical outcomes, yet these differences were not observed. These results suggest that fractures of the distal radius that heal with minor deformities are unlikely to have clinically relevant limitations and have no impact on patient perceived outcomes for patients above the age of 60 years. This study confirms this is true regardless of whether these fractures were treated operatively or nonoperatively.

Declaration of conflicting interests

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

Funding

The author(s) received no financial support for the research, authorship, and/or publication of this article.

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