The functional importance of malunion in distal radius fractures

Nadine HOLLEVOET, René VERDONK

The purpose of our study was to investigate which radiological parameter had the maximal detrimental effect on functional outcome following malunion of distal radius fractures. Sixty-four women over 40 years of age who had sustained low-energy wrist fractures were included in the study. The mean age of the patients was 64 years. We compared the ulnar variance, radial inclination and palmar tilt of the fractured wrist to the non-injured contralateral side on radiographs obtained after fracture healing. The functional outcome was assessed at a mean follow-up of 28 months. Wrist mobility, grip strength, and pain with daily activities were determined and combined to give a final outcome rating. An increase in ulnar variance was found to be the most important radiological parameter affecting functional outcome and the outcome tended to be influenced by age, hand dominance and the presence of articular involvement.

INTRODUCTION

The radiological end-result of distal radius fractures does not always correlate to the functional outcome. It has been reported that patients may experience no problems despite malunion (6). It is unclear as to which radiological parameter should be corrected in order to achieve the best functional outcome. In young adults the need for an anatomic reduction has been stressed. It has been suggested that a maximum of 10° of dorsal tilt, 15° of radial inclination, 2 mm of radial shortening and 2 mm of intra-articular incongruity may be accepted and carpal malalignment should be avoided (3). In elderly patients conflicting reports have been published about the influence of malunion on outcome. Some authors report no correlation between the clinical and radiological results (12) while others have reported worse results in patients with malunion (10). Both dorsal angulation and radial shortening have been associated with a poor functional outcome (2). Intra-articular involvement has been found to have little influence on the functional outcome of low-energy fractures in older postmenopausal women (6). The purpose of our study was to look for correlations between radiological parameters and functional outcome in distal radius fractures and to determine which radiological parameters should be corrected to achieve an optimal end-result. The parameters studied were ulnar variance, palmar tilt and radial inclination. We also looked for the influence of age, hand dominance and articular involvement on the functional outcome. To eliminate the confounding influence of concomitant ligamentous or cartilaginous injury, which is often present in high-energy fractures,

From the Orthopaedic Department of the University Hospital of Gent, Belgium.

Nadine Hollevoet, Orthopaedic Surgeon, University Hospital, De Pintelaan 185, B-9000 Gent, Belgium.

René Verdonk, Professor of Orthopaedic Surgery and Traumatology, Head of the Department of Orthopaedic Surgery and Physical Medicine, University Hospital, De Pintelaan 185, B-9000 Gent, Belgium.

Correspondence and reprints : Nadine Hollevoet, Department of Orthopaedic Surgery and Physical Medicine, University Hospital, De Pintelaan 185, B-9000 Gent, Belgium. E-mail : Nadine.Hollevoet@ugent.be.

only low-energy fractures were included in this study. The study population consisted of women older than 40 years who had sustained a fracture in a simple fall.

MATERIAL AND METHODS

Between September 1995 and September 1998, a total of 136 female patients over the age of 40 were treated in our hospital for distal radius fractures. Of these, a total of 37 patients were excluded for the purposes of this prospective study. The exclusion criteria were high-energy trauma (7 patients), prior ipsilateral wrist fractures (9 patients), prior contralateral wrist fractures (17 patients), and dementia (4 patients). Of the remaining patients, 20 were lost to follow-up and 15 were excluded as they did not have radiographs at final follow-up. Hence, 64 patients participated in the study, with a mean age of 64 years (range, 42 to 84 years). The study was approved by the medical ethics committee of our hospital and all of the patients gave informed oral consent. Thirty-three patients had an extra-articular or type A fracture according to the AO classification (11). Six had a type B (partial articular) and 25 a type C fracture (completely intra-articular). Half of the patients had a fracture involving the dominant hand. Most patients were still active and performing household tasks. The patients were treated by a variety of methods, i.e. only cast immobilisation (7 patients), closed reduction and cast immobilisation (7 patients), percutaneous pinning (43 patients), external fixation (3 patients) and volar plating for anterior displacement (4 patients).

Patients were evaluated with a mean follow-up of 28 months (range : 12 to 51 months). The passive range of movement of both wrists was measured with a goniometer. The flexion-extension, pronation-supination and ulnar-radial deviation ranges were expressed as a percentage of the uninjured contralateral wrist. The sum of these ranges of motion divided by 3 yielded the average total range of motion. The maximal grip strength was recorded using a Jamar dynamometer with the elbow in 90° of flexion and the forearm in neutral rotation. These results were also expressed as a percentage of the uninjured side. We used the pain score of Trumble *et al* (table I) and their combined outcome rating system, which is the sum of the total range of motion, pain relief and grip strength divided by 3 (15).

Lateral and anteroposterior radiographs taken six weeks after the fracture were compared with radiographs of the uninjured contralateral wrist and the differences in palmar tilt, ulnar variance and radial inclination were measured. Palmar tilt is the angle between a line perpendicular to the central axis of the radius and a line connecting the dorsal and palmar margins of the articular surface of the distal radius on the lateral view (fig 1). It is designated as positive if the tilt is in a volar direction and negative if there is a dorsal tilt. Ulnar variance and radial inclination were measured on anteroposterior radiographs (fig 2). Ulnar variance is the distance in millimeters between two parallel lines perpendicular to the central axis of the radius, one line passing through the distal articular surface of the ulna and the other through the medial articular surface of the distal radius. Ulnar variance is negative when the ulnar articular surface is more proximal with respect to the radial articular surface and positive if it is more distal. This is an accurate indication of the degree of radial shortening. Radial inclination is the angle between a line perpendicular to the central axis of the radius and the line connecting the radial and ulnar limits of the articular surface of the distal radius (8).

Multiple regression analysis was used to determine the correlations between radiological findings and clinical outcome and also the influence of confounding variables such as age, hand dominance and fracture type. Two-by-two corelations between radiological and clinical parameters were expressed using Pearson's correlation coefficients. The absolute value of this coefficient, whether negative or positive, indicates the degree of

Table I. — Scale used to evaluate pain relief (Trumble *et al*)

100	no pain with activity
90	some discomfort without limitation in activities
80	discomfort during performance of heavy labor or stressful daily living activities not requiring occupational or lifestyle changes
70	discomfort/pain prohibiting return to previous occupation, but allowing light recreational activities or activities of daily living
60	occasional discomfort/pain during even light recreational activities that does not preclude these activities or activities of daily living
50	pain with all activities noted above and occasionally with simple activities of daily living, but not limiting
40	pain that inhibits some simple activities of daily living
30	symptoms as noted above that can be relieved with an immobilising splint
20	symptoms requiring splinting and medication
10	symptoms requiring splinting, medication, and rest to relieve pain
0	unrelenting pain

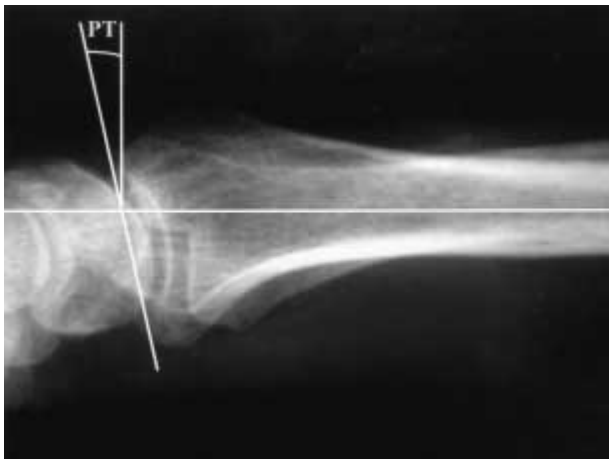

Fig. 1. — Measurement of palmar tilt (PT)

Fig. 2. — Measurement of ulnar variance (UV) and radial inclination (RI).

correlation. The Mann-Whitney U test was used to look for differences in clinical and radiological outcome between patients younger than 66 years and older than 65 years, between patients with a fracture at the dominant and non-dominant side, and between intra-articular and extra-articular fractures.

RESULTS

The range of movement, pain score, grip strength and overall outcome ratings are listed in table II. The complications encountered were transient symptoms of carpal tunnel syndrome in 6 patients, reflex sympathetic dystrophy in 7 patients, flexor tenosynovitis in two, trigger finger in one and extensor pollicus longus tendon rupture in one. At the final follow-up, one patient with reflex sympathetic dystrophy had persistent pain, while two patients had pain from trapeziometacarpal arthritis. The radiological results are shown in table III. Multiple regression analysis (table IV), showed significant correlations between ulnar variance and clinical outcome. There was no significant influence from the confounding variables except for age and fracture type with palmar tilt. The correlation coefficients between the clinical and radiological results for all patients (table V) demonstrated significant correlations between increase in ulnar variance and flexion-extension range ($p = 0.015$), grip strength ($p = 0.004$), pain ($p = 0.028$), and the combined clinical outcome rating ($p = 0.004$). Differences in palmar tilt and flexion-extension range were also significantly correlated ($p = 0.03$). When the study population was divided according to age (table VI) in patients younger than 66 years, the difference in ulnar variance correlated significantly with grip strength ($p = 0.005$), with flexion-extension range ($p = 0.03$), with pain ($p = 0.02$) and with the combined outcome ($p = 0.01$). Significant correlations were also found between palmar tilt and the flexion-extension range ($p = 0.01$) as well as the total range of motion ($p = 0.015$). Difference in radial inclination correlated significantly with pain ($p = 0.045$) and combined outcome ($p = 0.025$). In the older patients, correlation coefficients were lower and not significant. Correlation coefficients in patients with fractures of the dominant and non-dominant sides (table VII) showed that in the former group increase in ulnar variance correlated significantly with grip strength ($p = 0.004$) and with the combined outcome rating ($p = 0.02$). Difference in radial inclination correlated with the pronation-supination range ($p = 0.04$), with the total range of motion ($p = 0.04$), and with the combined outcome ($p = 0.02$). In patients with fractures of the non-dominant side, a significant correlation was observed between ulnar variance and flexion-extension

Table II. — Results of clinical examination in 64 wrists

	mean	minimum	maximum	SD
flexion-extension range	139°	85°	180°	20
flexion-extension range (%)	88	56	100	9
pronation-supination range	161°	100°	190°	17
pronation-supination range (%)	96	52	100	9
ulnar-radial deviation range	56°	15°	75°	14
ulnar-radial deviation range (%)	89	25	120	17
pain score	88	50	100	11
grip strength (%)	87	36	146	25
total range of motion (%)	91	54	108	10
combined outcome rating	88	49	109	12

% : as a percentage of the contralateral wrist.

Table III. — Radiological results of 64 wrists at fracture healing

	mean	minimum	maximum	SD
difference in palmar tilt	- 8°	- 41°	+ 16°	13
difference in radial angulation	- 4°	- 18°	+ 17°	5.5
difference in ulnar variance (mm)	+ 2	-1	+ 8	2

Table IV. — Multiple regression analysis between radiological findings and clinical outcome with age, hand dominance and fracture type as confounding variables

	R^2 *	Age **	Dominance **	Fracture type**
Palmar tilt	0.13 (P = 0.36)	-0.36 (P = 0.008)	0.041 (P = 0.76)	-0.29 (P = 0.033)
Radial inclination	0.13 (P = 0.40)	0.044 (P = 0.75)	0.26 (P = 0.060)	-0.207 (P = 0.14)
Ulnar variance	0.25 (P = 0.032)	0.029 (P = 0.84)	0.065 (P = 0.99)	-0.01 P = 0.64

* R^2 : Coefficient of determination.
** : partial correlation coefficient.

range (p = 0.002) as well as the total range of motion (p = 0.025). Radial inclination correlated significantly with the range of ulnar and radial deviation (p = 0.03) and with the total range of motion (p = 0.03). Grip strength (expressed as a percentage of the contralateral wrist) and combined outcome rating were significantly higher in patients with fractures of the dominant hand than in patients with fractures involving the non-dominant side. Mean grip strength for fractures in dominant hands was 97% and in non-dominant hands 79% (p = 0.003). The mean combined rating for fractures in dominant hands was 91 and in non-dominant hands 85 (p = 0.03). The mean age of patients with a fracture of the dominant hand was 62 years and of the non-dominant hand 66 years (p = 0.06). Correlations in patients with extra-articular and intra-articular fractures are presented in table VIII. In the former group we found significant correlations between ulnar variance and pain relief (p = 0.02), flexion-extension range (p = 0.001), grip strength (p = 0.009), and combined rating (p = 0.005). In the latter group, correlations were low and not significant. Patients with extra-articular

Table V. — Correlation coefficients between clinical outcome and radiological parameters

	fle/ext	pro/sup	uln/rad	tot ROM	pain	grip str	comb rat
ulnar variance	-0.30*	- 0.14	- 0.09	- 0.19	-0.28*	-0.36**	-0.35**
palmar tilt	0.27*	0.12	0.13	0.20	-0.11	0.21	0.17
radial inclination	- 0.03	0.21	-0.08	-0.02	0.08	0.05	0.07

* P < 0.05, ** P < 0.01.

fle/ext : flexion-extension range as a percentage of the contralateral wrist, pro/sup : pronation-supination range as a percentage of the contralateral wrist, uln/rad : ulnar-radial deviation range as a percentage of the contralateral wrist, tot ROM : total range of movement, pain : pain relief, grip str : grip strength, comb rat : combined rating.

Table VI. — Correlation coefficients in patients of 65 years or younger (N = 34) and in patients over 65 (N = 30)

	fle/ext	pro/sup	uln/rad	tot ROM	pain	grip str	comb rat
65 or younger							
ulnar variance	-0.37*	-0.14	0.09	-0.13	-0.40*	-0.48**	-0.43*
palmar tilt	0.43*	0.31	0.30	0.41*	-0.08	0.24	0.29
radial inclination	0.23	0.33	-0.25	0.38*	0.35*	0.33	0.38*
over 65							
ulnar variance	-0.23	-0.16	-0.25	-0.28	-0.13	-0.24	-0.25
palmar tilt	-0.07	-0.23	- 0.06	-0.07	-0.32	0.18	-0.02
radial inclination	-0.33	0.04	-0.31	-0.31	-0.21	-0.25	-0.32

* P < 0.05, ** P < 0.01.

fle/ext : flexion-extension range as a percentage of the contralateral wrist, pro/sup : pronation-supination range as a percentage of the contralateral wrist, uln/rad : ulnar-radial deviation range as a percentage of the contralateral wrist, tot ROM : total range of movement, pain : pain relief, grip str : grip strength, comb rat : combined rating.

Table VII. — Correlation coefficients in fractures of the dominant hand (N = 32) and non-dominant hand (N = 32)

	fle/ext	pro/sup	uln/rad	tot ROM	pain	grip %	comb rat
dominant							
ulnar variance	-0.10	-0.21	0.12	-0.04	-0.33	-0.51**	-0.41*
palmar tilt	0.32	0.21	0.18	0.26	-0.04	0.09	0.13
radial inclination	0.25	0.36*	0.28	0.37*	0.35	0.32	0.42*
non-dominant							
ulnar variance	-0.54**	-0.06	-0.28	-0.40*	-0.22	-0.25	-0.32
palmar tilt	0.30	0.11	0.10	0.21	-0.19	0.18	0.14
radial inclination	-0.32	-0.03	-0.38*	-0.39*	-0.13	0.03	-0.16

* P < 0.05, ** P < 0.01.

fle/ext : flexion-extension range as a percentage of the contralateral wrist, pro/sup : pronation-supination range as a percentage of the contralateral wrist, uln/rad : ulnar-radial deviation range as a percentage of the contralateral wrist, tot ROM : total range of movement, pain : pain relief, grip str : grip strength, comb rat : combined rating.

Table VIII. — Correlation coefficients in type A fractures (N = 33) and in type B + C fractures (N = 31)

	fle/ext	pro/sup	rad/uln	tot ROM	pain	grip %	comb rat
type A							
ulnar variance	-0.55**	-0.13	-0.19	-0.33	-0.39*	-0.46*	-0.48**
palmar tilt	0.35*	0.13	-0.07	0.13	-0.03	0.18	0.10
radial inclination	0.08	0.17	-0.30	-0.06	0.06	0.18	0.11
type B + C							
ulnar variance	-0.02	-0.15	0.004	-0.04	-0.13	-0.31	-0.23
palmar tilt	0.23	0.09	0.32	0.31	-0.17	0.22	0.24
radial inclination	-0.14	0.26	0.03	0.05	0.09	0.01	0.04

* $P < 0.05$, ** $P < 0.01$.

fle/ext : flexion-extension range as a percentage of the contralateral wrist, pro/sup : pronation-supination range as a percentage of the contralateral wrist, uln/rad : ulnar-radial deviation range as a percentage of the contralateral wrist, tot ROM : total range of movement, pain : pain relief, grip str : grip strength, comb rat : combined rating.

fractures were younger (mean age, 62 years) than patients with intra-articular fractures (mean age, 67 years) but the difference was not significant ($p = 0.08$). In extra-articular fractures the flexion-extension range averaged 90% of the normal wrist and in intra-articular fractures the mean value was 86%. The difference was significant ($p = 0.03$). We did not find other significant differences in clinical outcome between patients with intra- and extra-articular fractures. The radiological and clinical outcome was not significantly different between patients above 65 or under 66 years old.

DISCUSSION

Differing views have been expressed on the radiologic and clinical outcomes of distal radius fractures in the literature. Kelly *et al* (7) felt that for patients more than 65 years old a maximum of 30° of dorsal angulation and 5 mm of radial shortening could be accepted. Jacob *et al* (5) found that a dorsal angle of more than 20° and a radial inclination of less than 15° were associated with more complaints and patient dissatisfaction. However, Young and Rayan (19) did not find a correlation between radiological and clinical results in a study of 25 low-demand patients older than 60 years of age. Roumen *et al* studied patients above the age of 55 and did not find a correlation between radiological and clinical outcome (12), but radiological parameters were not separately evaluated. Gliatis *et al* (4) found that radial shortening had no effect on the outcome in young adults, but an increase in dorsal tilt and articular incongruity were important. Radiographs of the contralateral wrist were not used in this study, to assess the degree of radial shortening. We, however, feel that the increase in ulnar variance can be underestimated and the significance of radial shortening overlooked, if the normal wrist is not used for comparison. As the normal ulnar variance ranges from -3 mm to +2 mm (13), radiographs of the normal wrist have been advocated to allow for a true evaluation (18). Studies that have included both young and old patients have stressed the importance of radial shortening (15, 17), though others like Tsuzaki *et al* (16) found that radial shortening did not affect the outcome and that only dorsal tilt correlated with loss of flexion. Stoffelen *et al* (14) found that not only radial shortening of more than 4 mm lead to a bad result, but also a dorsal tilt of more than 5°and a lateral shift of more than 2 mm. When only elderly patients were studied, Board *et al* (2) stressed the importance of both the final dorsal angle and radial shortening in patients above 55 years of age treated by Kapandji pinning. In young patients Kopylov *et al* (9) found that axial shortening and joint incongruity correlated with the presence of minor degenerative changes 30 years later.

Of the few studies that have differentiated between high- and low-energy injuries, Gliatis *et al* (4) have reported no difference in outcome

between the two groups in young adults. However, displaced intra-articular fractures occurred more frequently with high-energy injuries.

Amongst the different scoring systems used for functional outcome assessment, the Gartland and Werley score has been used frequently (1, 12, 17, 18). However, we felt that this score did not solely reflect the functional result, as it included the degree of distal radius deformity within it. Hence, it could not be used for independent correlation of the functional outcomes with the degree of malunion.

In this study, we found that correlations between radiological results and clinical outcomes were not very substantial, possibly because many other factors determine the outcome. Increase in ulnar variance (axial radial shortening) was the most important radiological parameter for functional outcome in women older than 40 years after low-energy trauma. Correlations were influenced by factors like age, fracture type and hand dominance. With multiple regression analysis, however, we found that only age and fracture type influenced the importance of palmar tilt. Like many previous authors (2, 4, 16, 17), we did not find a significant correlation between loss of radial inclination and clinical outcome except in the subgroup of younger patients with fractures on the dominant side. In younger patients and in extra-articular fractures, the influence of the radiological parameters we studied was more obvious than in intra-articular fractures or in older patients. In our study, the correlation coefficients were lower and no longer significant in patients older than 65 years. This can be explained by the fact that pain and clinical outcome is directly related to functional demands (2) in this patient population.

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