Can the displacement of a conservatively treated distal radius fracture be predicted at the beginning of treatment?

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Abstract The aim of this study was to investigate whether the final displacement of conservatively treated distal radius fractures can be predicted after primary reduction. We analysed the radiographic documents of 311 patients with a conservatively treated distal radius fracture at the time of injury, after reduction and after bony consolidation. We measured the dorsal angulation (DA), the radial angle (RA) and the radial shortening (RS) at each time point. The parameters were analysed separately for metaphyseally “stable” (A2, C1) and “unstable” (A3, C2, C3) fractures, according to the AO classification system. Spearman’s rank correlations and regression functions were determined for the analysis. The highest correlations were found for the DA between the time points ‘reduction’ and ‘complete healing’ ($r=0.75$) and for the RA between the time points

‘reduction’ and ‘complete healing’ ($r=0.80$). The DA and the RA after complete healing can be predicted from the regression functions.

Résumé Le but de cette étude est d’analyser après traitements orthopédiques conservateurs les déplacements des fractures de l’extrémité inférieure du radius. Nous avons analysé les radiographies de 311 patients traités de cette façon après réduction et consolidation. Nous avons mesuré la dislocation dorsale DD, l’angle radial RA et le raccourcissement du radius RS. Ces paramètres ont été mesurés de façon séparée pour des fractures stables (A2, C1) et instables (A3, C2, C3), selon la classification AO. L’analyse de toutes ces données a permis de mettre en évidence une corrélation importante pour la dislocation dorsale DD ($r=0,75$) et pour l’angle radial RA ($r=0,80$). Les valeurs de ces données après consolidation sont prévisibles.

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Abbreviations

DA	dorsal angulation
DA _{injury}	at the time point ‘injury’
DA _{red}	at the time point ‘reduction’
DA _{end}	at the time point ‘complete healing’
RA	radial angle
RA _{injury}	at the time point ‘injury’
RA _{red}	at the time point ‘reduction’
RA _{end}	at the time point ‘complete healing’
RS	radial shortening
RS _{injury}	at the time point ‘injury’
RS _{red}	at the time point ‘reduction’
RS _{end}	at the time point ‘complete healing’
AO	Arbeitsgemeinschaft für Osteosynthesefragen (Association for the Study of Internal Fixation)

Introduction

Radius fractures constitute some 17% of all fractures [6]. They are the most common fractures in humans with an incidence of 2–3/1000 persons per year [25]. Optimal treatment is extremely important, as the injury-related loss of function in the wrist can lead to occupational disability or even a need for long-term care in elderly populations [5].

Distal radius fractures are usually treated conservatively. This involves the initial closed reduction of the fracture and fixation with a forearm cast for 5–6 weeks [6]. In many cases, predominantly good functional healing results are reported for the cast treatment [1, 2, 5, 24].

In 70% of cases, conservative treatment is associated with considerable displacement after complete healing has occurred [24]. As near-anatomical reduction appears to be associated with better wrist function [1], the degree of displacement after conservative treatment is frequently seen as the cause of the unfavourable functional outcomes [3, 4, 10].

Conservative treatment competes with open surgical reduction and fixation using different techniques of osteosynthesis [17]. The development of angle-stable palmar plate osteosynthesis in particular has led to a renaissance of the surgical technique in recent years. However, surgical treatment is associated with considerable risks, and surgical treatment should only be recommended to those patients for whom there is a high risk that conservative treatment could lead to an unsatisfactory functional result.

So far, only minor associations and contradictory results have been described for the predictive significance of the factors of initial dislocation [22], degree of radial shortening 1 week after reduction [15, 16, 19], loss of radial angle [15, 16], ulnar shortening [16], radial shortening [12] and dorsal angulation of the radial joint surface [14, 16] for the function after distal radius fractures. The low association and the contradictory results can be partly explained by the influence of other factors on the functional outcome such as age, osteoporosis [3], osteoarthritis and pre-existing degenerative changes in the radiocarpal joint [17].

Due to the multitude of influencing factors, it is almost impossible for the surgeon treating the patient to predict at the time of injury what functional outcome would be achieved with conservative treatment after consolidation of the fracture. At the same time, only one of the above-mentioned factors, the quality of reduction and fixation, can be influenced by the surgeon. Thus, the surgeon faces the following questions: What is the expected degree of dislocation after complete healing when cast treatment is used, and is this degree of dislocation acceptable or does it justify surgery?

Consequently, the aim of this study was to investigate whether a prediction can be made from the radiographs taken at the time of the accident and after reduction as to

which fracture, as classified according to the AO system, will have what degree of displacement after complete healing when conservative treatment is used.

These data could influence decisions on the indication for conservative or surgical treatment in clinical practice.

Material and methods

Adult patients with conservatively treated distal radial fractures were enrolled in this retrospective cohort study. Radiographs of the wrist taken in two planes at the time of injury, after reduction and after bony consolidation were available for 262 patients. Radiographs taken at only two of these three time points were available for an additional 49 patients. Thus, a total of 311 patients were enrolled in the study.

The dorsal angulation (DA), the radial angle (RA) and the radial shortening (RS) were determined on the radiographs using a standardised procedure.

The DA was determined between a line through the dorsal and palmar boundary points of the radial joint surface and the perpendicular to the longitudinal axis of the radial shaft on the lateral radiographs. The normal value for the volar inclination of 11° was deducted from this measured angle. The resulting difference represents the DA and is used for further comparison.

The RA was determined between a line through the radial and ulnar boundaries of the radial joint surface and the perpendicular to the longitudinal axis of the radial shaft on the dorsovolar (DV) radiographs.

The radial shortening (RS) was measured as the difference in axial direction of the radius between the radial epiphysis on the ulnar side versus the ulnar plateau on the DV radiograph (a shortening was noted as a positive value).

The three parameters were determined at the time of injury (DA_{injury} , RA_{injury} , RS_{injury}), after reduction (DA_{red} , RA_{red} , RS_{red}) and after complete healing had occurred (DA_{end} , RA_{end} , RS_{end}).

The cases were divided into groups according to the AO classification system. In each fracture group, the parameters at each time point were presented descriptively and compared with each other. In addition, Spearman's correlation of each parameter at the time point 'injury' was calculated for each of the other parameters at the time points 'reduction' and 'end'. In the same way, the correlation of each parameter at the time point 'reduction' was determined for each of the other parameters at the time point 'end'. For correlations whose Spearman's correlation coefficient was $r > 0.5$, the linear regression model $y = ax + b$, the 95% confidence intervals of the regression coefficients a and b and the coefficient of determination r^2 were presented.

Results

Of the 311 patients, 143 were women and 168 were men. Thus, the proportion of women is 46% and the proportion of men is 54%. The median patient age was 68 years (min./max.: 15/100 years). Of the fractures, 151 (49%) were classified as A2, 79 (25%) as A3, 48 (15%) as C1, 29 (9%) as C2 and 4 (1%) as C3 according to the AO classification system.

The median DA was 20 and 18° for the A2 and C1 fractures, respectively. With a median of 26 and 24°, respectively, the DA was higher for the metaphyseally unstable A3 and C2 fractures (Table 1). The median DA was adjusted by approximately 40% by the reduction, irrespective of the type of fracture. However, by the time complete healing occurred, about half the adjustment of the reduction was lost again, so that it is only possible to achieve a median adjustment of approximately 20% of the original dorsal dislocation with conservative treatment (Table 1).

The median RA is only slightly influenced by the injury and the reduction in all classification groups, so that there are near-anatomical RA values at the time of complete healing.

At the time of injury, the unstable fractures were more frequently found to have a radial shortening of more than 2 mm. Only 29 stable fractures and 33 unstable fractures gained at least 2 mm in length due to the reduction. Based on the number of those who had a radial shortening of at least 2 mm at the time of injury, this represents 38.2% of the stable fractures and 44.6% of the unstable fractures. With most fractures, the reduction only resulted in a change in radial length, in relation to the ulna, of less than or equal to 1 mm. After reduction, 59 (34.7%) of the stable fractures and 46 (45.5%) of the unstable fractures lost 2 mm of radial length by the time of complete healing. With conservative treatment, only 14 stable and 14 unstable fractures actually achieved a gain in length of at least 2 mm after reduction that was maintained until complete healing had occurred. Based on the number of those who had a radial shortening of at least 2 mm at the time of injury, this represents 8.8% of the stable fractures and 14.7% of the unstable fractures.

The DA shows a significant correlation between the different time points ($r>0.5$). Also the RA and the radial

shortening correlate with each other at each of the different time points. There is no correlation between different parameters or between one of the parameters and age (Table 2).

The strongest correlations were found between DA_{red} and DA_{end} ($r=0.75$) and between RA_{red} and RA_{end} ($r=0.80$) (Figs. 1 and 2).

Regression functions were calculated from the clusters of points. These functions can predict the displacement at the time of complete healing on the basis of the known dislocation at the time of injury or after reduction.

The regression function (Table 3) shows, for instance, that a measured dorsal angulation of 17° after reduction will result in a DA of 21.14° at the time of complete healing (Fig. 3).

Discussion

This study investigates whether the dorsal and radial dislocation and the radial shortening at the time of injury and after reduction have a predictive value for the radiological healing outcome of a distal radius fracture.

The results show that all three parameters correlate within the individual time points. However, there are no correlations between the parameters.

The strongest correlation was observed between RA_{red} and RA_{end}. According to Herzog and Schiewe [7], the median RA is 20–25°; the minimum and maximum are given as 15 and 35°, respectively. Given these normal values, we find in this study that the RA does not deviate significantly from the normal value. No significant changes were observed within the investigated time points. Evidently, the dislocation in the coronary plane is only slight. Therefore, it does not make much sense to make a therapy decision on the basis of this parameter. Jacob et al. [9], for instance, show that even conservatively treated elderly patients with an RA of < 15° do not have a poor clinical outcome after complete healing. The criteria according to Poigenfürst [23], which are also frequently used for stability assessment, merely define the not very precise term “zone of comminution” but do not consider the RA at

Table 1 Dorsal angulation (°) at the time of injury, after reduction and after complete healing, separately for metaphyseally stable (A2, C1) and unstable (A3, C2) fractures

	A2		C1		A3		C2	
	Med. (°)	Min./max. (°)	Med. (°)	Min./max. (°)	Med. (°)	Min./max. (°)	Med. (°)	Min./max. (°)
Injury	20	0/64	18	0/54	26	0/54	24	14/48
Reduction	12	–8/44	14	2/29	16	0/38	16	0/26
Complete healing	16	8/54	19	0/44	20	–2/42	20	–6/42

Table 2 Correlations of the individual parameters with each other

	DA _{red}	DA _{end}	RA _{red}	RA _{end}	RS _{red}	RS _{end}	Age
DA _{injury}	0.62 265	0.58 253	-0.17 267	-0.24 253	0.04 267	0.26 254	0.22 274
DA _{red}		0.75 271		-0.25 271		0.25 269	0.26 291
RA _{injury}	-0.30 265	-0.24 253	0.74 267	0.75 263	-0.15 267	-0.26 254	-0.12 274
RA _{red}		-0.17 272		0.80 273		-0.22 271	-0.19 293
RS _{injury}	0.26 265	0.19 253	-0.22 267	-0.31 253	0.55 267	0.53 254	0.35 274
RS _{red}		0.04 272		-0.27 273		0.50 271	0.38 293

Values greater than 0.5 are highlighted in grey. The top number is the correlation coefficient, and the bottom number is the sample size on which the correlation is based

all. Only Leone et al. [15] define an RA of $< 10^\circ$ as a predictive factor for instability, but with low significance ($p < 0.05$).

The three correlations within the radial shortening parameter narrowly reach the required significance level ($r > 0.5$). The correlations are weak. With r values of 0.502–0.547, predictions derived from these correlations would only apply to 25–30% of individuals in a population. Clinical usability cannot be deduced on the basis of the data of this investigation. There is also another reason why the

Fig. 1 Correlation and regression function ($y = 0.99x + 4.31$) of the dorsal angulation at the time points 'reduction' and 'complete healing' **Fig. 2** Correlation and regression function ($y = 0.95x + (-0.23)$) of the radial angle at the time points 'reduction' and 'complete healing'

predictive significance of the radial shortening must be viewed critically.

There is considerable normal anatomical variance. In 16%, there is an ulna plus variance, in 61% the radius and the ulna are of equal length (ulna zero variance) and in 23% there is an ulna minus variance [8, 21]. Without examining and knowing the anatomical situation of the contralateral side, it is thus not reliably possible to determine the degree of shortening after injury. Although there are measurable relative changes, one can never be certain whether a gain in length achieved by reduction and fixation corrects the full injury-related loss or only some of it. Many studies attribute a significant influence on the clinical outcome to the radial shortening [3, 4, 10, 15, 18, 20]. Frequently, the limit of 2 mm, after which functionally unsatisfactory outcomes must be expected, is considered to be clinically significant [2, 10, 15, 19]. Ultimately, this value implies that it is actually a longitudinal dislocation which results in the 84% with an ulna minus or ulna zero variance; however, the exact extent remains unclear. In the 16% with an ulna plus variance, it is not clear whether a radial shortening measured after injury is caused by the injury or whether it is physiological.

According to Herzog and Schiewe [7], the median anatomical radial joint angle in the sagittal direction is 10° and fluctuates between 0 and 20° . However, unlike in the coronary plane, considerable differences between the three measuring times are observed in the sagittal plane in this study. What stands out is that while the injury-related dislocation can be partly corrected by the reduction, this effect is then partly lost again by the time of healing. This

Table 3 Regression function, r^2 values and 95% confidence intervals (CI) for the regression coefficients a and b of all correlations with a correlation coefficient $r > 0.5$

Data set	Prediction	Regression function ($y=ax+b$)	r^2	95% CI a	95% CI b
Dorsal angulation					
Injury	Compl. healing	$y=0.44x+8.46$	0.30	0.36–0.52	6.33–10.59
Reduction	Compl. healing	$y=0.99x+4.31$	0.60	0.89–1.10	2.64–5.97
Injury	Reduction	$y=0.36x+5.98$	0.33	0.30–0.43	4.37–7.58
Radial angle					
Injury	Compl. healing	$y=0.71x+5.15$	0.54	0.62–0.79	3.40–6.89
Reduction	Compl. healing	$y=0.95x+(-0.23)$	0.65	0.86–1.04	-2.11–1.64
Injury	Reduction	$y=0.60x+8.51$	0.54	0.53–0.67	7.04–9.98

means that a reduction and fixation of a dislocation in the sagittal plane is difficult and can thus quickly prove too much for conservative treatment. Against this background, the predictive statement ($DA_{end}=0.99DA_{red}+4.31$) from the correlation between DA_{red} and DA_{end} achieves clinical significance. The degree of dorsal angulation at the time of complete healing could be predicted for 60% of the individuals of a population on the basis of the known dorsal dislocation after reduction. The DA has great significance for the function of the wrist, as it influences the degree of flexion and results in an incongruence in the distal radioulnar joint (DRUJ) [1, 11, 23, 25]. It would thus be desirable to be able to estimate the degree of dislocation at a time when it is still possible to influence it. Anzarut et al. [1] therefore describe the DA as the most important parameter as, according to them, it is responsible for the degree of pain and the restriction of the hand's grip strength. This is explained by incongruence in the DRUJ.

It is surprising that the measured results of the fractures classified as stable and unstable do not differ markedly at any of the time points. The comparison shows that the unstable fracture groups have slightly greater dislocations in all directions; however, the differences are not significant. When the fractures were classified according to the AO system, the stability was not assessed on the basis of the primary dislocation, but the absence of (or failure to

detect) a dorsal zone of comminution was rated as a stable situation. However, in view of the results of this study, a stable fracture would have to be classified as a fracture with little or no dislocation. Previous studies have shown that the assessment of the stability of a radius fracture is subject to a considerable source of error, irrespective of the classification system used [4, 9, 10, 20]. The AO system also results in incorrect classification in 40% of cases when conventional radiographs are used [1, 12].

Therefore, a comparison of stable and unstable fractures is not possible on the basis of the data from this study. On the contrary, the data show that even fractures without primary dislocation can develop a secondary dislocation by the time of complete healing under conservative treatment, and that fractures with a considerable dislocation after reduction and fixation in a cast can heal in an anatomical position. Against this background, the definition of the stability of a distal radius fracture is more than ever unclear.

Another limitation of this study is that the prediction of the radiological healing outcome has only limited validity for the actual clinical outcome of the patient concerned. Clinical and radiological scores show considerable differences in up to 40% of cases [3, 4, 10]. Although good reduction results are more frequently associated with good and very good clinical outcomes [3, 10, 24], there are evidently other factors besides the osseous position that

Fig. 3 Time-dependent course of a distal radius fracture (A0: 23-C2, female, aged 68). From left to right: images after injury, after reduction and after complete healing. The DA (3) and the RA (1) match the predicted values of the regression functions from Table 7

very closely ($DA_{injury}=29^\circ$, $RA_{injury}=15^\circ$, $DA_{red}=17^\circ$, $RA_{red}=18^\circ$, $DA_{end}=21^\circ$, $RA_{end}=18^\circ$). The RS (2) behaves in a very similar manner ($RS_{injury}=5$ mm, $RS_{red}=3$ mm, $RS_{end}=4$ mm)

have a considerable effect on the clinical outcome and patient satisfaction. An effect on the outcome has been demonstrated in the past for various factors, such as the patient's age [18] or osteoporosis and pre-existing osteoarthritic changes in the radiocarpal joint [5, 13]. While none of these factors can be influenced therapeutically, the bone healing outcome can. Against this background, the results of this study are of considerable clinical interest; due to the possibility of predicting the end result, it can be decided immediately after the reduction, on the basis of the radiograph, whether the fracture should receive further conservative treatment or whether surgical treatment should be considered.

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References

1. Anzarut A, Johnson JA, Rowe BH, Lambert R, Blitz S, Majumdar S (2004) Radiologic and patient-reported functional outcomes in an elderly cohort with conservatively treated distal radius fractures. *J Hand Surg [Am]* 29:1121–1125
2. Beumer A, McQueen MM (2003) Fractures of the distal radius in low-demand elderly patients: closed reduction of no value in 53 of 60 wrists. *Acta Orthop Scand* 74:98–100
3. Dayican A, Unal VS, Ozkurt B, Portakal S, Nuhoglu E, Tumoz MA (2003) Conservative treatment in intra-articular fractures of the distal radius: a study on the functional and anatomic outcome in elderly patients. *Yonsei Med J* 44:836–840
4. Dóczy J, Fröhlich P (1996) The classification of distal radial fractures and the diagnostic value (in German). *Unfallchirurg* 99:323–326
5. Einsiedel T, Becker C, Stengel D, Schmelz A, Kramer M, Daexle M, Lechner F, Kinzl L, Gebhard F (2006) Do injuries of the upper extremity in geriatric patients end up in helplessness? A prospective study for the outcome of distal radius and proximal humerus fractures in individuals over 65 (in German). *Z Gerontol Geriatr* 39:451–461
6. Goldfarb CA, Yin Y, Gilula LA, Fisher AJ, Boyer MI (2001) Wrist fractures: what the clinician wants to know. *Radiology* 219:11–28
7. Herzog KH, Schiewe R (1963) The anatomical prerequisite for chronic injuries of the wrist (in German). *Z Orthop Ihre Grenzgeb* 97:311–321
8. Hulthén O (1928) Über anatomische Variationen der Handgelenkknöchel. *Acta Radiol* 9:155–169
9. Jakob M, Mielke S, Keller H, Metzger U (1999) Clinical results of conservative treatment of distal radius fractures in patients older than 65 years (in German). *Handchir Mikrochir Plast Chir* 31:241–245
10. Karnezis IA, Panagiotopoulos E, Tyllianakis M, Megas P, Lambiris E (2005) Correlation between radiological parameters and patient-related wrist dysfunction following fractures of the distal radius. *Injury* 36:1435–1439
11. Kopylov P, Johnell O, Redlund-Johnell I, Bengner U (1993) Fractures of the distal end of the radius in young adults: a 30-year follow-up. *J Hand Surg [Br]* 18:45–49
12. Kreder HJ, Agel J, McKee MD, Schemitsch EH, Stephen D, Hanel DP (2006) A randomized, controlled trial of distal radius fractures with metaphyseal displacement but without joint incongruity: closed reduction and casting versus closed reduction, spanning external fixation and optional percutaneous K-wires. *J Orthop Trauma* 20:115–121
13. Lauritzen JB, Schwarz P, Lund B, McNair P, Transbøl I (1993) Changing incidence and residual lifetime risk of common osteoporosis-related fractures. *Osteoporos Int* 3:127–132
14. Lehnert T, Wohlers J, Streng W (2006) Dosisvariation mit einem direkten Selen-Flachbilddetektor - Eine Studie zur Dosisreduktion bis an die Grenzen der diagnostischen Verwertbarkeit. *Fortschr Röntgenstr* 178:278–286. DOI 10.1055/s-2006-926536
15. Leone J, Bhandari M, Adili A, McKenzie S, Moro JK, Dunlop RB (2004) Predictors of early and late instability following conservative treatment of extra-articular distal radius fractures. *Arch Orthop Trauma Surg* 124:38–41
16. van der Linden W, Ericson R (1981) Colles' fracture. How should its displacement be measured and how should it be immobilized? *J Bone Joint Surg Am* 63:1285–1288
17. Mann FA, Wilson AJ, Gilula LA (1992) Radiographic evaluation of the wrist: what does the hand surgeon want to know? *Radiology* 184:15–24
18. Nesbitt KS, Failla JM, Les C (2004) Assessment of instability factors in adult distal radius fractures. *J Hand Surg [Am]* 29:1128–1138
19. Ochmann S, Frerichmann U, Armsen N, Raschke MJ, Meffert RH (2006) Ist die Behandlung der instabilen distalen Radiusfraktur beim älteren Menschen mittels Fixateur externe nicht mehr indiziert? *Unfallchirurg* 109:1050–1057
20. Oestern HJ (1999) Distale Radiusfrakturen Teil 1. Grundlagen und konservative Therapie. *Chirurg* 70:1180–1192
21. Palmer AK, Werner FW (1984) Biomechanics of the distal radioulnar joint. *Clin Orthop Relat Res* 187:26–36
22. Pogue DJ, Viegas SF, Patterson RM, Peterson PD, Jenkins DK, Sweo TD, Hokanson JA (1990) Effects of distal radius fracture malunion on wrist joint mechanics. *J Hand Surg [Am]* 15:721–727
23. Poigenfürst J (1980) Brüche am distalen Unterarmende. Einteilung der Bruchformen und Indikation. *Hefte Unfallheilkd* 148:53–59
24. Porter M, Stockley I (1987) Fractures of the distal radius. Intermediate and end results in relation to radiologic parameters. *Clin Orthop Relat Res* 220:241–252
25. McQueen M, Caspers J (1988) Colles fracture: does the anatomical result affect the final function? *J Bone Joint Surg Br* 70:649–651