Carpal Malalignment in Malunion of the Distal Radius and the Effect of Corrective Osteotomy

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Abstract

Introduction Malunions of the distal radius often induce carpal malalignment. Two different types can be distinguished: an adaptive midcarpal malalignment (so-called CIA wrist: carpal instability, adaptive) and a radiocarpal malalignment (dorsal translation of the whole carpus). The effect of distal radial osteotomy on the carpal alignment has hardly been studied.

Material and Methods 31 wrists in 31 patients (mean age 44 years) with malunion of the distal radius after a Colles fracture were treated with a corrective osteotomy. The patients were divided on basis of effective radio-lunate flexion (ERLF) in the two patterns of carpal malalignment. The radiographic changes were evaluated.

Results There were 20 patients with midcarpal malalignment ($\text{ERLF} \leq 25^\circ$) and 11 with radiocarpal malalignment ($\text{ERLF} > 25^\circ$). There was a correction of radial tilt and ulnar variance in both groups. There was a significant improvement of the carpal alignment in the midcarpal malalignment group, up to normal parameters. Neither age nor delay between fracture and osteotomy correlated. In the radiocarpal malalignment group a significant effect on the ERLF was observed. In the patients with dorsal plating 70% of the hardware had to be removed.

Conclusion Distal radial osteotomy is a reliable technique for correction of the deformity at the distal end of the radius and carpal malalignment.

Keywords

- carpus
- distal radius fracture
- instability
- malunion
- osteotomy

Malunions are frequent after distal radius fractures.^{1,2} Changes of carpal alignment in malunion of the distal radius are thought to be an adaptive process of the carpus to realign the hand either at the midcarpal or at the radiocarpal level when there is abnormal dorsal angulation of the distal radius. There is no ligament or capsular disruption. The incidence of carpal malalignment is correlated with the functional outcome.³ Two distinct patterns have been observed. Type 1 is midcarpal instability, in which the proximal carpus tends to face dorsally in line with the dorsally angulated articular surface of the distal radius with a compensatory flexion of the midcarpus (capitate) in an unstable, zigzag pattern of the wrist.^{4,5} Type 2 is dorsal subluxation of the carpus, with dorsal translation of the entire carpus with respect to the distal radius (radiocarpal malalignment). Gupta et al described two patterns of carpal

alignment based on the effective radiolunate flexion (ERLF) measured on the radiographs.⁶ The ERLF describes the relative flexion of the lunate in relation to the articular surface of the distal radius. When the lunate and the fracture fragment both rotate dorsally as one piece (Type 1) the lunate's axis and the axis of the distal radial articular surface maintain a collinear relationship, while the ERLF is measured as 0. When there is dorsal rotation of the distal radius fracture fragment alone without taking the lunate with it, the lunate maintains a collinear relationship with the capitate but is dorsally subluxed relative to the radius articular surface (type 2). Type 1 therefore has a value of less than 25° , and type 2 is more than 25° .

The aim of the osteotomy of the distal radius is to correct the malunion is to improve the wrist alignment. The effect of the osteotomy on the carpal alignment is less clear.

An osteotomy of the distal radius can restore volar tilt, ulnar variance, radial inclination and radial height.

Abnormal alignment and motion of the carpal bones leads to mechanical overload of the radiocarpal and midcarpal joint. This overload can cause ligament attenuation, synovitis, and progressive dynamic instability.^{5,7} In 1984 Taleisnik and Watson⁵ reported 13 patients with symptoms of midcarpal pain and instability after malunited fractures of the distal radius. They performed a corrective osteotomy in 3 patients. They demonstrated that a corrective osteotomy can result in relief of symptoms and resulted in correction of the radiolunate and lunocapitate relationship. Minami and Ogino⁸ reported one case of midcarpal instability following a malunited fracture of the distal radius, where an osteotomy resulted in complete relief of symptoms. McQueen and Wakefield⁹ noted a restoration of carpal alignment in 21 of 23 patients who underwent a distal radial osteotomy using non-bridging external fixation for dorsal malunion. Carpal malalignment was defined as the displacement on a lateral view of the longitudinal axis of the capitate either dorsal or volar to the longitudinal axis of the radius.¹⁰ Other studies failed to confirm these findings. In a series of 122 cases Sennwald et al.¹¹ could not obtain good results with radial osteotomy in cases with carpal instability.

Personal Studies

We studied the carpal malalignment in malunion of the distal radius and the effect of a distal osteotomy.¹² The inclusion criteria were (a) malunion of a distal radius fracture, (b) initial fracture type Colles, and (c) a full complement of radiological films available (preoperative and follow-up anteroposterior and lateral radiographs). There were 11 men and 20 women. The average age was 44 years (range 16 to 76 years). The average time between trauma and corrective surgery was 3 years and 10 months (range 3 months to 30 years). The mean time of radiological follow-up was 7 months (range 6 to 18 months). All operations were performed by the senior author (LDS). The techniques described by Fernandez¹³ were followed. Twenty-two patients underwent an opening wedge osteotomy with interposition of a corticancellous iliac crest bone graft (one in combination with a Sauvé-Kapandji [S-K] procedure and one with a Darrach procedure), one with interposition of cancellous bone graft from the proximal ulna and eight patients underwent a closing wedge osteotomy (4 in combination with an S-K procedure and 4 combined with ulnar shortening osteotomy). The approaches were volar in 21 patients (14 opening wedge osteotomy, 7 closing wedge osteotomy) and dorsal in 10 (9 opening wedge osteotomy and 1 closing wedge). For the ulnar procedures an additional approach was used. Preoperatively and at the final clinical assessment, standard anteroposterior (AP) and lateral radiographs were taken. On the AP radiographs three measurements were used to evaluate the malunion: radial inclination, radial height, and ulnar variance. The presence or absence of an ulnar styloid fracture was noted. Radial inclination was measured as the angle between a line drawn parallel to the distal articular surface and a line drawn

perpendicular to the long axis of the radius. The ulnar variance was measured between a line tangential to the lunate facet of the radial articular surface, perpendicular to the long axis of the radius, and a line tangential to the distal extent of the ulnar head, perpendicular to the long axis of the radius. Radial length, also called radial height, was measured by determining the longitudinal difference between a line perpendicular to the long axis of the radius drawn at the radial styloid and another line tangential to the lunate facet of the radial articular surface.

On the lateral radiographs five measurements were taken: dorsal tilt of the distal radius, the scapholunate angle (SLA), radiolunate angle (RLA), radioscapoid angle (RSA), and capitulunate angle (CLA). Flexion was considered as positive, extension as negative. Dorsal tilt was measured, in degrees, as the angle formed by the intersection of one line perpendicular to the longitudinal axis of the radial shaft and a second line drawn through the apices of the palmar and the dorsal rims of the radius. The lunate axis was drawn as a line perpendicular to the line tangential to the poles of the lunate, while the scaphoid axis was the line tangential to the palmar outlines of the proximal and distal poles. The capitate axis was the line between the middle of the proximal and distal articular surface of the capitate. SLA was measured as the angle between the axes of the scaphoid and lunate. RLA and RSA were measured as the angles between the axis of radius and that of the lunate and the scaphoid, respectively. CLA was measured as the angle between the axis of lunate and capitate.

ERLF was calculated by the formula: $ERLF = \text{Dorsal tilt} + 11^\circ$ (mean volar tilt) + RLA. ERLF measures the movement of the lunate that has occurred secondary to fracture displacement.¹⁴ Patients were divided into two groups based on the ERLF. The first group with ERLF less than or equal to 25° (group 1) ($N = 20$) corresponds with type 1 or midcarpal malalignment. The second group with ERLF more than 25° (group 2) ($N = 11$), corresponds to type 2 or radiocarpal malalignment. The paired-samples *t*-test was used to determine preoperative and follow-up differences of each angle. The level of significance was set at $P\text{-value} < 0.05$.

Results

Radiographs demonstrate an improvement of the dorsal tilt, radial inclination, ulnar variance, and radial length (► **Table 1**).^{15,16} The average preoperative dorsal tilt was 12° ($SD \pm 14^\circ$). Postoperatively, the average volar tilt was -6° ($SD \pm 10^\circ$) ($p = 0.0000003$). The radial inclination improved from 18° ($SD \pm 8^\circ$) to 21° ($SD \pm 8^\circ$) ($p = 0.009$). The ulnar variance improved from an average of 2 ($SD \pm 3$ mm) to 0 ($SD \pm 2$ mm) ($p = 0.00002$). The preoperative radial length was 9 ($SD \pm 3$ mm). Postoperatively it improved to 10 ($SD \pm 4$ mm) ($p = 0.006$). There were 12 patients with an associated fracture of the ulnar styloid.

The first group with ERLF less than or equal to 25° (type 1 or midcarpal malalignment) occurred in 20 patients (mean age 42 years, mean value: 0.8° ($SD \pm 16^\circ$)). Preoperatively the ERLF was more than 25° (type 2 or radiocarpal malalignment)

Table 1 Global radiographic findings at preoperative and final examination

	Normal value ($\pm$ SD)	Preoperative value ($\pm$ SD)	Follow-up value ($\pm$ SD)	p-Value
Dorsal tilt ¹	-10° ($\pm$ 6°)	12 ($\pm$ 14°)	-6° ($\pm$ 10°)	0.0000003*
Radial inclination ¹	22° ($\pm$ 3°)	18 ($\pm$ 8°)	21° ($\pm$ 8°)	0.009*
Radial height ²	8 ($\pm$ 14) mm	9 ($\pm$ 3) mm	10 ($\pm$ 4) mm	0.006*
Ulnar variance ³	neutral	2 ($\pm$ 3) mm	0 ($\pm$ 2) mm	0.00002*

The values are given as the mean.

¹Normal value from Stoffelen et al 1998.¹⁵

²Normal values from Gupta et al 2002.⁶

³Normal value as mentioned by Brandon et al 2007.¹⁶

*Significant.

2 Division of patients in two groups on the basis of effective radiolunate flexion

Group	Preoperative	Dorsal tilt	Mean age	Mean value ERLF
ERLF $\leq$ 25° (group 1)	20 patients	10° (SD)	42 patients	0.8° (SD 16)
ERLF > 25° (group 2)	11 patients	17° (SD)	46 patients	33° (SD 6)

in eleven patients (36%, mean age 46 years, mean value: 33° [SD $\pm$ 6°]). Postoperatively only four patients had an ERLF > 25°; they were all correlated with a persistent dorsal tilt. In group 1 there was a significant improvement ($p < 0.05$) of the dorsal tilt, radial height, and ulnar variance (**Table 3**). Radial inclination preoperatively was 18° (SD $\pm$ 7°), which improved to 21° (SD $\pm$ 6°) postoperatively ($p = 0.08$). There was also a significant improvement of the SLA, RLA, and CLA. The preoperative SLA of 63° (SD $\pm$ 13°) was reduced to an average of 56° (SD $\pm$ 10°) ($p = 0.02$). Twelve patients in this group had a SLA exceeding 60° preoperatively. The RSA did not show significant change between the preoperative and follow-up radiographs. RLA preoperatively was -20° (SD $\pm$ 18°) and improved to -7° (SD $\pm$ 18°) ($p = 0.0005$).

The average preoperative CLA was 10° (SD $\pm$ 18°). Postoperatively it was 0° (SD $\pm$ 15°) ($p = 0.004$).

In the second group a significant improvement of radial tilt and ulnar variance was seen (**Table 4**). The average preoperative radial inclination was 19° $\pm$ 9°, postoperatively 23° $\pm$ 10° ($p = 0.06$). Preoperatively radial height measured 10 $\pm$ 3 mm; postoperatively this was 11 $\pm$ 4 mm ($p = 0.08$). Postoperatively all four of these radiographic parameters were considered as normal values. The effect on the carpal angles was not significant. The average preoperative ERLF of 33° (SD $\pm$ 6°) decreased to 9° (SD $\pm$ 15°) ($p = 0.0008$). In the second group, with exclusion of those patients with residual dorsal angulation after surgery, the ERLF was reduced to normal: preoperative 33° (SD $\pm$ 7°) and postoperative 2° (SD $\pm$ 12°) ($p = 0.002$).

Table 3 Radiographic findings for group 1 (ERLF $\leq$ 25°) at preoperative and final examination

	Normal value ($\pm$ SD)	Preoperative value ($\pm$ SD)	Follow-up value ($\pm$ SD)	p-Value
Dorsal tilt	-10° ($\pm$ 6°)	10° ($\pm$ 15°)	-7° ($\pm$ 11°)	0.0002*
Radial inclination	22° ($\pm$ 3°)	18° ($\pm$ 7°)	21° ($\pm$ 6°)	0.08
Radial height	8-14 mm	8 ($\pm$ 3) mm	10 ($\pm$ 4) mm	0.04*
Ulnar variance	Neutral	2 ($\pm$ 2) mm	0 ($\pm$ 2) mm	0.003*
Scapholunate angle	50° ($\pm$ 7°)	63° ($\pm$ 13°)	56° ($\pm$ 10)	0.02*
Radiolunate angle	10° ($\pm$ 6°)	-20° ($\pm$ 18°)	-7° ($\pm$ 18°)	0.0005*
Capitolunate angle	-12° ($\pm$ 2°)	10° ($\pm$ 18°)	0° ($\pm$ 15°)	0.004*
Radioscaphoid angle	60° ($\pm$ 4°)	43° ($\pm$ 18°)	48° ($\pm$ 15°)	0.1
ERLF	0°	1° ($\pm$ 16°)	-3° ($\pm$ 20°)	0.5

The values are given as the mean. Normal values for the carpal angles from Stoffelen et al 1998.¹⁵

*Significant.

Table 4 Radiographic findings for group 2 (ERLF > 25°) at preoperative and final examination

	Normal value ($\pm$ SD)	Preoperative value ($\pm$ SD)	Follow-up value ($\pm$ SD)	p-Value
Dorsal tilt	-10° ($\pm$ 6°)	17° ($\pm$ 10°)	-4° ($\pm$ 10°)	0.0005*
Radial inclination	22° ($\pm$ 3°)	19° ($\pm$ 9°)	23° ($\pm$ 10°)	0.06
Radial height	8–14 mm	10 ($\pm$ 3) mm	11 ($\pm$ 4) mm	0.08
Ulnar variance	Neutral	3 ($\pm$ 3) mm	0 ($\pm$ 1) mm	0.002*
Scapholunate angle	50 ($\pm$ 7°)	51° ($\pm$ 9°)	51° ($\pm$ 11)	1
Radiolunate angle	10° ($\pm$ 6°)	5° ($\pm$ 10°)	-3° ($\pm$ 11°)	0.6
Capitolunate angle	-12° ($\pm$ 2°)	-14° ($\pm$ 11°)	-14° ($\pm$ 13°)	0.9
Radioscaphoid angle	60° ($\pm$ 4°)	57° ($\pm$ 11°)	53° ($\pm$ 10°)	0.3
ERLF	0°	33° ($\pm$ 6°)	-9° ($\pm$ 15°)	0.0008*

The values are given as the mean.

*Significant

There was no significant difference in patients' ages, dorsal tilt, and radial shortening between the two types of carpal malalignment ($p > 0.1$). There was no significant correlation with the interval between the fracture and the osteotomy and the type of carpal malalignment ($p = 0.5$).

Eleven patients had their implants removed. Seven of them had a dorsal approach (70% hardware removal), and four had a volar approach (19% hardware removal). This is a significant difference (Fisher exact test $p = 0.013$, and chi-square test

Figure 1 midcarpal instability with an unstable, zigzag pattern of the wrist: the proximal carpus tends to face dorsally in line with the dorsally angulated articular surface of the distal radius with a compensatory flexion of the midcarpus (capitate)

Figure 2 dorsal subluxation of the carpus, with dorsal translation of the entire carpus with respect to the distal radius (radio-carpal malalignment).

Figure 3 The two patterns of carpal alignment were identified based on the effective radio-lunate flexion (ERLF) measured on the radiographs: type 1 (b) has a value of less than 25°, type 2 (c) of more than 25°

$p = 0.006$). Two revision operations had to be performed: the first for implant failure, the second due to nonunion. One year after an opening wedge osteotomy, one patient had a lunocarpitate fusion due to persisting midcarpal instability.

Conclusion

We could demonstrate that a radial osteotomy has a beneficial effect on the carpal alignment in patients with the midcarpal and radiocarpal malalignment pattern. In the first group the pre- and postoperative ERLF was considered being normal. In the second group there was a significant effect on the ERLF, but it could not be completely restored.

Complication rates were low, with only two revisions. Dorsal plating has a significantly higher rate of plate removal as mentioned in previous reports.^{15,16}

Conflict of Interest

None

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