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Original Research

Carpal Joint Malalignment With Distal Radius Malunion and Factors in Correction After Distal Radius Osteotomy

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A R T I C L E I N F O

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Purpose: There is a paucity of data regarding recommendations on when to correct for distal radius malunions and if the initial severity of the radiographic outcomes is correlated with the ability to correct to baseline. We evaluated the effects of distal radius corrective osteotomy on preoperative carpal joint malalignment resulting from distal radius malunions, correlated injury severity and osteotomy timing to radiographic outcomes, and developed a straightforward classification system for predicting radiocarpal and midcarpal maladaptive patterns.

Methods: A retrospective review included 26 patients (27 wrists) who reported initial closed treatment for a distal radius fracture and who subsequently underwent a corrective osteotomy for malunion. Data included patient demographics, range of motion, preoperative fracture deformity, fracture deformity correction, and preoperative and postoperative radiographic measurements of the radiocarpal and midcarpal alignment patterns.

Results: Of 27 dorsally angulated malunions, 16 were classified as type 1 midcarpal adaptation and 11 as type 2 radiocarpal adaptation. The midcarpal group showed significant improvements in distal radius and carpal alignment parameters after surgery, except for the ulnar variance. The radiocarpal group showed significant improvements in distal radius and carpal alignment parameters, except for the radiolunate angle, radioscaphoid angle, and capitolunate angle. The radiocarpal group exhibited an overall decrease in range of motion compared with that of the midcarpal group. Severity of the fracture and time taken from injury to corrective osteotomy correlated with the ability to correct carpal radiographic parameters in dorsally angulated malunions of the distal radius, especially beyond 40 weeks.

Conclusions: The severity of the initial fracture and time taken from injury to corrective osteotomy correlate with the ability to correct radiographic parameters in dorsally angulated malunions of the distal radius. Early correction of distal radius malunions is recommended, especially in radiocarpal malalignment patterns. A useful analysis for predicting midcarpal and radiocarpal adaptation patterns is the direct measurement of the distal articular surface of the radius to the lunate, termed the relative-radiolunate angle.

Type of study/level of evidence: Therapeutic IV.

Fractures of the distal radius are some of the most common injuries seen by hand and upper-extremity surgeons.[1] Distal radius fractures account for 18% of fractures in the elderly and 25% of fractures in the pediatric population.[1] Despite our knowledge of clinical outcomes and predictors of instability for distal radius fractures (distal radiolulnar joint and ulnar styloid involvement), many heal in a malunited position.[2] Although extra-articular fracture malunion of the distal radius is well known for having a high potential to alter the kinematics of the distal radioulnar joint, fractures without articular involvement or incongruity have also been reported to cause problems within the radiocarpal and midcarpal joints.[3,4] These two carpal malalignment patterns are classified as type 1 (midcarpal malalignment)[5,6] or type 2 (radiocarpal malalignment) and are identified by the effective radiolunate

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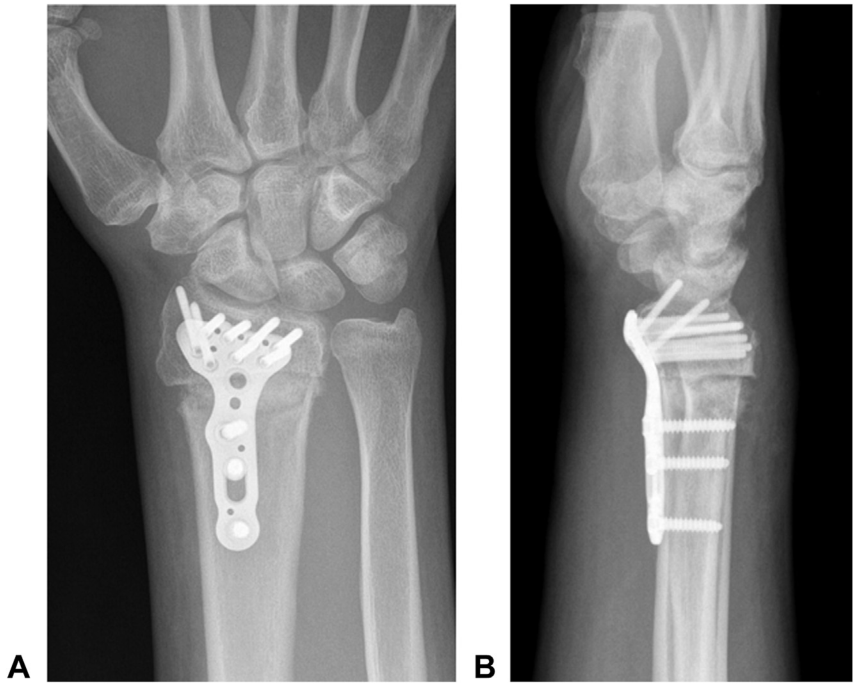

Figure 1. Postoperative radiographs of dorsal distal radius osteotomy with plate fixation and bone grafting. **A** Postoperative posteroanterior view. **B** Postoperative lateral view.

flexion (ERLF) angle, which compares the axis of the distal radius with the lunate. In type 1midcarpal malalignment, the distal radius is displaced along a similar axis as the lunate, resulting in an ERLF angle of <25°.[7] In type 2 radiocarpal malalignment, the displaced distal radius is angulated in a different axis compared with that of the flexed lunate, resulting in an ERLF angle of >25°.

Type 1 malalignment is more common than type 2 malignment with Gupta et al[7] reporting 83% midcarpal malalignments in 118 fracture cases and De Smet et al[6] reporting 65% midcarpal malalignments in 31 fracture cases.[6,7] Furthermore, patients with type 2 malalignment showed a higher likelihood of not completely restoring their ERLF angle in comparison with type 1 malalignment patients after corrective osteotomy. However, addressing these carpal malalignments is important because they can negatively affect function of the hand.[8]

The purpose of this study was to evaluate the radiographic alignment of the radiocarpal and midcarpal joints of the wrist in the setting of distal radius malunion, and after corrective osteotomy of the distal radius malunion, to determine to what degree the preoperative malalignment improves after corrective osteotomy. We also investigated if the magnitude of the radiographic deformity or time taken for corrective osteotomy could influence the radiographic outcomes. We hypothesized that the increased severity of the initial malalignment and increased time duration from the original fracture to the definitive corrective osteotomy will have a deleterious effect on the ability of the malalignment to be corrected after osteotomy, but there will be no differences in correction achieved between the two malalignment types.

Material and Methods

Patients

After Rush University Medical Center's instituional review board approval, a retrospective review of all patients who underwent treatment at a major academic medical center with a corrective osteotomy for distal radius malunion over a 10-year period (2006–2015) was performed. The inclusion criteria included all patients aged >18 years who reported an initial closed treatment (reduction and cast immobilization) for an extra-articular distal radius fracture and who subsequently underwent a corrective osteotomy for malunion of the distal radius with a minimum radiographic follow-up of 12 weeks. The exclusion criteria included fracture patterns other than a primarily extra-articular bending mechanism (such as shear or die punch fractures), previous surgery for the distal radius fracture or malunion, any known concomitant or previous trauma or preexisting conditions that could alter the carpus, and <12 weeks of radiographic follow-up. Indications for distal radius osteotomy included malunions with malalignment co-occurring with distal radial-ulnar joint incongruity, or persistent pain, weakness, and loss of function. Patient charts were reviewed to obtain demographic, preoperative, and postoperative follow-up data.

Radiographic Evaluation

The radiographic assessment was performed using preoperative and postoperative (≥12 weeks) standard posteroanterior and lateral radiographs of the wrist (Fig. 1 A, B). The alignment was assessed by measuring the radial inclination, radial height, ulnar variance, and volar tilt (Table 1). The assessment for carpal maladaptive patterns was performed using the radiolunate angle, radioscaphoid, angle, and capitolunate angles (Table 1).[7,9,10]. Specific to dorsally angulated fractures, we used the previously described ERLF angle that evaluates the relationship between the radius and the lunate differentiating the malalignment pattern as type 1 (midcarpal) or type 2 (radiocarpal) malalignment.[11,12]

In particular, ERLF is measured by the formula ERLF = Dorsal tilt + 11° (mean volar tilt) + radiolunate angle on lateral radiographs. Flexion is considered a positive value, whereas extension is considered a negative value. The dorsal tilt was measured from the

Table 1
Dorsal Angulated Radiographic Outcomes: Radiocarpal Versus Midcarpal*

Parameters	Normal Value (SD)	Midcarpal (n = 16)			Radiocarpal (n = 11)		
		Preoperative	Postoperative	*P*	Preoperative	Postoperative	*P*
Mean radial height (mm)	11 (3)	4.9 (0.2 to 8.4)	9.8 (4.3 to 11.6)	.02†	5.6 (0.3 to 6.8)	10.4 (5.9 to 11.3)	.03†
Radial inclination	22° (3°)‡	12.3° (7.9° to 15.3°)	20.5° (17.0° to 26.0°)	.02†	10.9° (5.6° to 14.8°)	23.8° (20.8° to 25.8°)	.03†
Ulnar variance (mm)	0.9 (4)§	2.6 (0.7 to 4.4)	1.1 (0.0 to 2.5)	.07	5.3 (2.5 to 9.2)	1.3 (0.0 to 3.6)	.04†
Volar tilt	11° (6°)‡	−19.9° (−24.1° to −11.7°)	1.9° (−2.0° to 4.1°)	< .01†	−28.1° (−38.0° to −24.5°)	2.7° (−0.4° to 4.6°)	< .01†
Radiolunate angle	10° (6°)‡	−20.1° (−30.3° to −12.0°)	−7.5° (−14.9° to −4.1°)	< .01†	−10.8° (−13.0° to 5.7°)	−0.5° (−6.1° to 5.7°)	.07
Radioscaphoid angle	60° (4°)‡	44.5° (36.4° to 54.1°)	53.3° (47.0° to 58.6°)	.01†	49.0° (43.4° to 55.1°)	56.5° (52.7° to 58.7°)	.77
Capitolunate angle	−12° (2°)‡	5.7° (2.1° to 10.7°)	−0.9° (−9.2° to 8.5°)	.01†	6.5° (−3.4° to 8.3°)	2.0° (−10.9° to 3.3°)	.43
ERLF†	0°	10.1° (1.5° to 16.4°)	−0.6° (−3.6° to 5.8°)	< .01†	31.0° (27.4° to 38.3°)	12.6° (5.0° to 15.4°)	< .01†
Relative-radiolunate angle	N/A	−2.0° (−11.9° to 2.4°)	−6.5° (−16.4° to 0.8°)	.01†	19.9° (10.9° to 25.4°)	9.4° (0.8° to 16.8°)	< .04†

* Data represented as medians (first quartile–third quartile).
† Statistically significant *P* value < .05.
‡ Normal values from Stoffelen et al.[10]
§ Normal values from by Bushnell and Byrum.[9]

angle created between the line perpendicular to the longitudinal axis of the radial shaft and the line drawn connecting the dorsal and volar lips of the radius on the lateral radiograph. The radiolunate angle was measured through the longitudinal axis of the radius and the lunate. Finally, 11° was added to the equation in order to adjust for the average volar tilt in the population.

To compare against the ERLF angle concept, a relative-radiolunate angle (RRLA) was constructed by measuring the angle between a longitudinal axis perpendicular to the distal articular surface of the radius and a longitudinal axis perpendicular to the distal articular surface of the lunate (Fig. 2).

Postoperative radiographs were assessed for healing of the osteotomy, with union defined as bridging bone on three out of four cortices. All digital images were analyzed using a picture archiving and communication system (Opal-RAD, Konica Minolta Medical Imaging Inc) that permitted angular measurements to the level of 0.1°.

Surgical Technique

All surgical procedures were performed by three fellowship-trained hand and upper extremity-surgeons (M.S.C., J.J.F., and R.W.W.) at a single institution. The choice of implant was by surgeon's discretion, non-randomized, or based on physician preference, and similar surgical techniques and rehabilitation protocols were followed for all patients. Our database search yielded 55 corrective osteotomies in 54 patients. Five wrists were excluded for shear fracture patterns; 11 wrists for revision osteotomies; five wrists for skeletal immaturity; and seven with <12 weeks of follow-up. This left 27 wrists in 26 patients available for inclusion.

Eleven surgeries were performed using a modified Henry volar approach, and 16 cases required dual volar and dorsal approaches, typically with the dorsal portion for application of bone graft. All cases were treated with volar plating, except one that required dorsal plate fixation. Corrective osteotomies were performed using a saw, and the cuts were finished with an osteotome. To fill the defect created by the osteotomy, autograft was obtained from the ipsilateral olecranon in 11 cases and the iliac crest in five cases. Allograft was used in five cases. Six cases did not require bone grafting. No surgical procedures were directly performed on the carpals or on the radiocarpal or midcarpal ligamentous structures.

Statistical Analysis

An independent statistician performed statistical analysis using Stata 12 (StataCorp LP, College Station, TX) statistical software. Continuous data were analyzed and compared with a two-tailed independent Student *t* test, and Mann-Whitney U test, or Wilcoxon signed-rank test for variables with nonnormal distributions. Significance was set at $P < .05$. Correlation among multiple continuous data were analyzed with Pearson's correlation analysis.

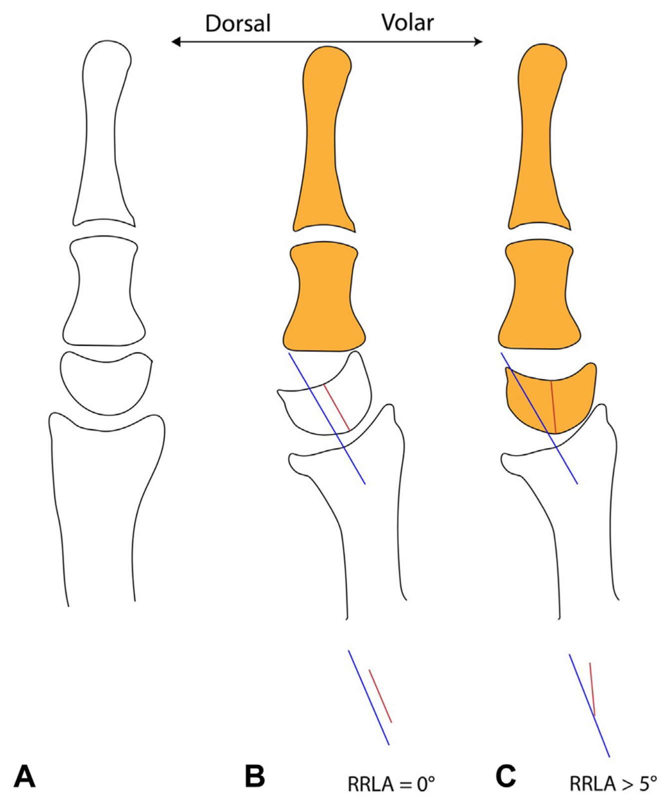

Figure 2. Malalignment patterns and RRLA. **A** Normal radiocarpal and midcarpal alignment. **B** Type 1: midcarpal malalignment. **C** Type 2: radiocarpal malalignment.

Results

Patients

After applying the exclusion criteria, 27 dorsally angulated distal radius malunions (26 patients) with a minimal follow-up of at least

Table 2
Demographics

Inclusion	27 Dorsal Angulated Malunions (26 Patients)
Median age (interquartile range)	55 y-old (23)
Median time from initial injury to distal radius corrective osteotomy (interquartile range)	25.5 wk (19)
Median time to follow-up (interquartile range)	42 wk (137)
Sex	11 M, 15 F
Side dominance	25 right-hand dominant, 1 left-hand dominant
Injury	16 right-sided injury, 10 left-sided injury
Mechanism of injury	24 falls on outstretched hand 1 motor vehicle accident 1 impact on metal object
Complications	None

12-weeks were examined. The median age, median time taken from initial injury to the corrective osteotomy, the median follow-up time, gender, side dominance, injury side, mechanism of injury, and complications were calculated (Table 2).

Range of Motion

Table 3 illustrates the active range of motion seen in each patient before surgery and at their last follow-up. Range of motion was recorded as wrist flexion, wrist extension, forearm pronation, and forearm supination expressed as medians with interquartile ranges. The radiocarpal group exhibited improvements in flexion, extension, pronation, and supination, whereas the midcarpal group did not show any significant improvement in extension.

Dorsally Angulated Radiographic Outcomes

Using the ERLF classification system, 16 patients (59%) were grouped into the type 1 midcarpal adaptation, and 11 patients (41%) were grouped into type 2 radiocarpal adaptation.

The midcarpal group showed considerable improvements in all distal radius and carpal alignment parameters after surgery, but not in ulnar variance (Table 1). Of the 16 patients classified into a type 1 midcarpal adaptation, 14 exhibited only midcarpal adaptations, one displayed both midcarpal and radiocarpal adaptations, and one showed no carpal adaptations beyond the preoperative ERLF value. Moreover, 14 of the 16 patients reported a preoperative RRLA <5° (range −33.2°−2.6°). The patient that exhibited both midcarpal and radiocarpal maladaptive patterns reported a preoperative ERLF of 17.5° and a preoperative RRLA of 12.7°.

The radiocarpal group showed marked improvements in distal radius and carpal alignment parameters but not in the radiolunate angle, radioscaphoid angle, or capitolunate angle (Table 1). All patients within this group reported a RRLA range from 8.4° to 31.3°. Of the 11 wrists included into the radiocarpal group, two displayed isolated radiocarpal adaptations, whereas nine exhibited both midcarpal and radiocarpal adaptations. Of the 11 wrists 10 within the radiocarpal group showed a preoperative RRLA >5° (8.4°−31.3°). The initial severity of the dorsal malunion angulation correlated with the ability to correct the ERLF angle. (Table 4).

The time taken from the initial injury to the corrective osteotomy correlated with the ability to correct the radiolunate angle, but not with the capitolunate or effective radiolunate angles (Table 5). It was more difficult to correct the radiolunate angle with increased time from injury to the corrective osteotomy, particularly beyond 40 weeks (P = .02). The malalignment differences were more difficult to correct to baseline for radiocarpal maladaptive patterns in postop ERLF and RRLA compared with those of the midcarpal maladaptive group. Finally, all patients healed their osteotomies, with a median time to union of 12 weeks (interquartile range of 6 weeks).

Discussion

The results of this study demonstrate greater difficulty in achieving correction in radiocarpal adaptive patients back toward normal compared with the midcarpal patients, which may suggest that when a radiocarpal pattern is identified, there should be added emphasis on early correction and patient counseling that it represents a scenario where correction will likely be more challenging, albeit with unclear knowledge of the clinical implications of the ongoing radiocarpal adaptive change. Furthermore, patients with radiocarpal maladaptive patterns exhibited lower range of motion in both preoperative and postoperative values, thus reinforcing the severity of the deformity. It should be noted that the preoperative dorsally angulated deformity was greater in the radiocarpal group (31.0°) when compared with the midcarpal group (10.1°). This raises the question of whether the decreased ability to achieve carpal correction in the radiocarpal group is because of the type of the deformity (radiocarpal vs midcarpal) or because a radiocarpal deformity patient on average simply has a greater starting dorsally angulated deformity.

Patients in the midcarpal group, with its tendency toward less preoperative dorsal deformity, reported only a 7% incidence of a concomitant radiocarpal deformity pattern, thus a simpler deformity. Conversely, patients with a primary radiocarpal deformity, with their greater preoperative dorsal deformity, reported an 82% incidence of a concomitant midcarpal deformity pattern. This suggests that the primary radiocarpal deformity is a herald of a more complex pattern overall that benefits from careful correction and an awareness that complete radiographic correction may be harder to achieve.

This study shows that timing of the osteotomy is important and does matter, with 40 weeks being the closest conversion point (P = .06) after which there is greater difficulty in getting the adaptive changes to correct back to normal radiographic parameters. Jupiter and Ring[13] evaluated 20 patients that showed early and late reconstructions of distal radius malunions. The early reconstruction was at a mean of eight weeks, and late osteotomy was at a mean of 40 weeks. They recommended earlier corrective osteotomy because of improved clinical results with respect to return to work, pain, motion, and grip strength, but did not look at whether timing correlated to the correction of radiographic parameters.[13]

De Smet et al[6] showed improved alignment in both midcarpal and radiocarpal malalignments but did not get full correction of the radiocarpal malalignment in their study, which may support the hypothesis that earlier intervention may make a difference as well.[6,11]Additionally, DeSmet et al[6] did not look at the initial severity of the fracture, which may contribute to the inability to fully correct carpal malalignments. In a large study of 122 patients, Senwald et al[14] showed improved radiographic appearance but could not obtain good clinical results with radial osteotomy after correcting for malalignments.

Verhaegen et al[11] performed a retrospective review on 31 patients treated with corrective osteotomy of the distal radius. They looked at radiocarpal and midcarpal malalignment and found that age and time taken from fracture to correction did not have an effect on the carpal alignment.[6] However, the details of the timing and follow-up are not clear in this study.

Table 3
Range of Motion of Radiocarpal and Midcarpal Groups*

ROM	Midcarpal Group (n = 8)			Radiocarpal Group (n = 6)		
	Preoperative	Postoperative	*P*	Preoperative	Postoperative	*P*
Extension	47.5° (27.5)	60.0° (18.8)	0.52	32.5° (27.5)	50.0° (16.3)	0.03†
Flexion	50.0° (28.8)	65.0° (13.3)	0.02†	32.5° (9.5)	55.0° (18.8)	0.02†
Pronation	60.0° (28.8)	80.0° (27.5)	0.01†	52.5° (10.0)	75.0° (30.0)	0.03†
Supination	60.0° (33.8)	80.0° (10.0)	0.02†	55.0° (22.5)	77.5° (20.0)	0.03†

Abbreviation: ROM, range of motion.
* Values are given as the median with interquartile range within parentheses.
† Statistically significant *P* value < .05.

Table 4
Correlation Between Dorsal Malunion Initial Severity to Postoperative Radiocarpal Adaptations*

Initial Severity	Postoperative RLA (*P*)	Postoperative CLA (*P*)	Postoperative ERLF (*P*)
Preoperative height	0.19 (0.35)	−0.16 (0.94)	−0.41 (0.03†)
Preoperative tilt	−0.04 (0.88)	−0.16 (0.12)	0.39 (0.04†)
Preoperative variance	0.13 (0.5)	0.04 (0.66)	0.40 (0.04†)

Abbreviations: CLA, capitolunate angle; ERLF, effective radiolunate flexion; RLA, radiolunate angle.
* Values are given as correlation coefficient.
† Statistically significant *P* value < .05.

Table 5
Dorsal Malunion Time to Osteotomy Correlated With Carpal Adaptations*

	Postoperative RLA (*P*)	Postoperative CLA (*P*)	Postoperative ERLF (*P*)
Time to Osteotomy	0.47 (0.01†)	−0.31 (0.11)	−0.08 (0.67)

Abbreviations: CLA, capitolunate angle; ERLF, effective radiolunate flexion; RLA, radiolunate angle.
* Values are given as correlation coefficient.
† Indicate statistically significant *P* value < .05

This study predicted the midcarpal and radiocarpal maladaptive patterns by measuring the RRLA and classifying maladaptive patterns based on a preoperative RRLA of more than 5° or less than 5°. When compared with the previous ERLF classification system, this does not require any calculation and is directly measured on radiographs. Although both of these methods are useful guides in predicting midcarpal and radiocarpal maladaptive patterns, there are instances where patients do not follow this rule. Thus, it is important to consider radiographs and the clinical picture as a whole.

Van Cauwelaert de Wyels et al[15] evaluated clinical and radiographic outcomes in 21 distal radius osteotomies in dorsally and volarly angulated malunions. They particularly found improvement in volar tilt of 27° in volar bending malunions and improvement in dorsal tilt of 25° in dorsally angulated malunions.[15] Our study showed similar improvement in the distal radius radiographic parameters, and in addition, we showed improvement in the radiographic measurements involving the carpus, such as the radiolunate angle, radioscaphoid angle, and capitolunate angle for dorsally angulated injuries. Strengths of this study include the length of follow-up of over a year and the incorporation of a newer method of evaluating the ERLF angle called the RRLA.

The current study was limited by its retrospective design, the lack of any comparison group, and the small number of patients included, which limited the power of the statistical analysis. The small cohort of patients is because this procedure is a small percentage of a hand surgery practice. Future studies should be directed at correlating the radiographic changes we identify with clinical results, both from the standpoint of differential range of motion and differential development of post-traumatic arthritis in the long term for the two different adaptation patterns. Further investigation in the form of a multicenter study with a larger patient population could be powered to try to find predictors of what patients will or will not have the best likelihood of correcting their adaptive deformity with corrective osteotomy. This study was a short-term study aimed primarily at identifying the adaptive patterns and their ability to conform in the short-term; however, long-term radiographic and clinical outcome studies would be highly beneficial to see if further radiographic correction can occur over time, and whether there are differential rates of post-traumatic degenerative changes between those who do and do not correct their alignment.

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References

1. Nellans KW, Kowalski E, Chung KC. The epidemiology of distal radius fractures. *Hand Clin*. 2012;28(2):113–125.
2. Myderrizi N. Factors predicting late collapse of distal radius fractures. *Malays Orthop J*. 2011;5(3):3–7.
3. Lozano-Calderón SA, Brouwer KM, Doornberg JN, Goslings JC, Kloen P, Jupiter JB. Long-term outcomes of corrective osteotomy for the treatment of distal radius malunion. *J Hand Surg Eur Vol*. 2010;35(5):370–380.
4. Park MJ, Cooney WP, Hahn ME, Looi KP, An KN. The effects of dorsally angulated distal radius fractures on carpal kinematics. *J Hand Surg Am*. 2002;27(2):223–232.
5. Cooney WP, Dobyns JH, Linscheid RL. Complications of Colles' fractures. *J Bone Joint Surg Am*. 1980;62(4):613–619.
6. De Smet L, Verhaegen F, Degreef I. Carpal malalignment in malunion of the distal radius and the effect of corrective osteotomy. *Jnl Wrist Surg*. 2014;3(3):166–170.
7. Gupta A, Batra S, Jain P, Sharma SK. Carpal alignment in distal radial fractures. *BMC Musculoskelet Disord*. 2002;3(1):14.

8. Bickerstaff DR, Bell MJ. Carpal malalignment in Colles' fractures. *J Hand Surg Br*. 1989;14(2):155−160.
9. Bushnell BD, Bynum DK. Malunion of the Distal Radius. *J Am Acad Orthop Surg*. 2007;15(1):27−40.
10. Stoffelen D, De Mulder K, Broos P. The clinical importance of carpal instabilities following distal radial fractures. *J Hand Surg Br*. 1998;23(4):512−516.
11. Verhaegen F, Degreef I, De Smet L. Evaluation of corrective osteotomy of the malunited distal radius on midcarpal and radiocarpal malalignment. *J Hand Surg Am*. 2010;35(1):57−61.
12. Taleisnik J, Watson HK. Midcarpal instability caused by malunited fractures of the distal radius. *J Hand Surg*. 1984;9(3):350−357.
13. Jupiter JB, Ring D. A comparison of early and late reconstruction of malunited fractures of the distal end of the radius. *J Bone Joint Surg*. 1996;78(5):739−748.
14. Sennwald G, Fischer W, Stähelin A. [Malunion of the distal radius and its treatment. Apropos of 122 radii]. *Int Orthop*. 1992;16(1):45−51.
15. Van Cauwelaert de Wyels J, De Smet L. Corrective osteotomy for malunion of the distal radius in young and middle-aged patients: an outcome study. *Chir Main*. 2003;22(2):84−89.