

External Fixation of Distal Radius Fractures: Effect of Distraction and Duration

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Purpose To assess the effects of the amount of distraction across the wrist and the duration of fixator placement on the clinical outcome of patients with distal radius fractures treated with external fixation.

Methods A total of 42 patients with closed distal radius fractures were treated with a spanning external fixator plus supplementary percutaneous K-wires over a 6-year period. All fractures were extra-articular (A type) or simple intra-articular (C type). Twenty-four of these patients were evaluated retrospectively for clinical and radiographic outcomes at an average follow-up time of 22 months (range, 4–49 months). The amount of distraction attained by the fixator was determined by measuring the carpal height ratio on plain radiographs. Wrist and forearm range of motion were recorded, as well as grip and pinch strength. Standard radiographs were taken to evaluate healing and bony alignment.

Results Using the Gartland Werley classification, there were 11 excellent, 10 good, and 3 fair results. Statistical analysis indicated that a higher carpal height ratio at the initial reduction positively correlated ($p = .041$) with an excellent outcome. Duration of external fixation did not have a significant impact on the final outcome within the parameters studied ($p = .891$). Average wrist range of motion at follow-up was as follows: flexion, 54.1° (75% of the contralateral side); extension, 59.0° (78%); radial deviation, 18.0° (85%); ulnar deviation, 22° (73%); pronation, 79.0° (95%); and supination, 76.6° (93%). None of the individual components of range of motion were negatively correlated with higher carpal height ratio at fixator application or duration of fixation, within the parameters studied.

Conclusions Moderately increased distraction of the carpus at the initial fracture reduction is correlated with improved clinical outcome and does not have an adverse affect on subsequent wrist range of motion. (*J Hand Surg* 2009;34A:1605–1611. © 2009 Published by Elsevier Inc. on behalf of the American Society for Surgery of the Hand.)

Type of study/level of evidence Therapeutic IV.

Key words Distal radius, fractures, external fixation, distraction, duration.

WITH THE RECENT advent of improved implants used for open reduction and internal fixation of distal radius fractures, external fixation of these fractures has fallen out of favor. Cur-

rently, volar fixed-angle fixation with plates and screws is popular; however, published studies have not shown that this technique yields clearly superior results in the long term over other methods of treatment.^{1,2} Further-

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more, if adequate reduction in unstable fractures can be obtained by distraction and closed manipulation, external fixation with or without the use of percutaneous K-wires has been shown to be an excellent means of treatment.³⁻⁷ In opposition to this technique, several reports in the literature have discouraged the use of external fixators by associating it with complication rates ranging from 10% to 61%. These include pin site problems, loss of reduction, poor patient tolerance, and stiffness.⁸⁻¹² However, the complication of stiffness, which is often mentioned, has not clearly been substantiated by the literature.

It has been debated whether this postoperative stiffness is due to the severity of the original injury or the effect of distraction of the external fixator. In a frequently quoted study, Kaempffe et al.¹³ described a negative correlation between postoperative outcomes and the amount of distraction imparted by the external fixator. The amount of distraction was quantified by measuring carpal height ratio (CHR) on plain radiographs. However, 85% of these patients had excellent or good clinical results, and all outcome measures including range of motion (ROM) were not statistically negatively correlated with distraction imparted by the external fixator as measured by CHR. This association with external fixation and stiffness has been explored in several other studies as well.^{14,15}

The purpose of our study was to evaluate the clinical outcome of patients with closed distal radius fractures treated with external fixation. Our outcome measures are functional outcome using the Gartland and Werley classification,¹⁶ ROM, and grip and pinch strength. We analyzed the effects of carpal distraction, as measured by the CHR at initial reduction, and the duration of external fixation of the wrist. Common complications associated with external fixation, such as pin track infections, loss of reduction, and patient tolerance, were also evaluated.

MATERIALS AND METHODS

Over a 6-year period, 42 patients with distal radius fractures were treated with external fixation with or without supplementary percutaneous pins as deemed necessary by the operating surgeon. None of these patients underwent open reduction and internal fixation with plates or screws. Of these patients, 24 were available for complete follow-up examination and were evaluated in a retrospective fashion for functional and radiographic outcome at an average postoperative time of 22 months (range, 4-49 months). Of the 24 patients, 18 had more than 1 year of follow-up. Of the 6 patients with less than 1 year of follow-up, their average fol-

low-up time was 5.3 months. However, the average duration of fixator placement in this group was slightly less (45 days) than the over 1-year follow-up group (50 days). Thus, the shorter term group was clinically evaluated at an average of 16 weeks after fixator removal. Institutional review board approval was obtained from our university.

The patient population is from a level 1 trauma center and many patients were lost to follow-up. The 24 subjects available for follow-up included 13 men and 11 women, with an age range of 20 to 79 years, with a mean age of 40 years. There were 9 right-sided injuries and 15 left, with 13 of 24 involving the dominant side. All the fractures were closed and ranged from Frykman class I to class IV.¹⁷ There were 5 A2 fractures, 11 A3 fractures, 5 C1 fractures, and 3 C2 fractures, as graded by the AO/OTA classification.¹⁸ There were no shearing or B-type fractures in this group.

A uniplanar, external fixator was used in all cases and was in place for an average time period of 49 days (range, 21-84 days). Two pins were placed in the radial shaft and 2 in the second metacarpal (Fig. 1). The fixator was applied within 24 hours of the fracture in 17 patients. For the remaining 7 patients, the fixator was applied at an average of 9.6 days after failed closed treatment. When deemed necessary, supplementary K-wires were placed across the distal radius fracture fragments for added stability or for reduction of articular displacement that could not be aligned with ligamentotaxis. The fixator was typically used as a reduction tool with initial overdistracted, flexion, and ulnar deviation applied and then insertion of supplementary K-wires if necessary. After final reduction, the external fixator was readjusted into a neutral position and we ensured that full metacarpophalangeal flexion could easily be achieved. Supplementary smooth wires were used in 18 patients, with 2 or 3 K-wires of 1.6- (0.062-in) or 1.1-mm (0.045-in) size used. Finger and elbow ROM exercises were begun at the first postoperative visit. All patients were enrolled in a structured therapy program at that point, which typically began within 2 weeks of surgery. Therapy was continued and progressed to light strengthening at the 3- to 4-week period. Pin site care was taught to the patients and consisted of one-half-strength hydrogen peroxide cleaning with a cotton swab once a day.

We took x-rays at initial placement of the fixator, at 1 week, at 3 weeks postoperatively, and at the time the fixator was removed. All fixators were removed in the office at an average of 49 days after the original surgery. Measurements obtained from radiographs were as follows: CHR, radial inclination, distal radius volar tilt,

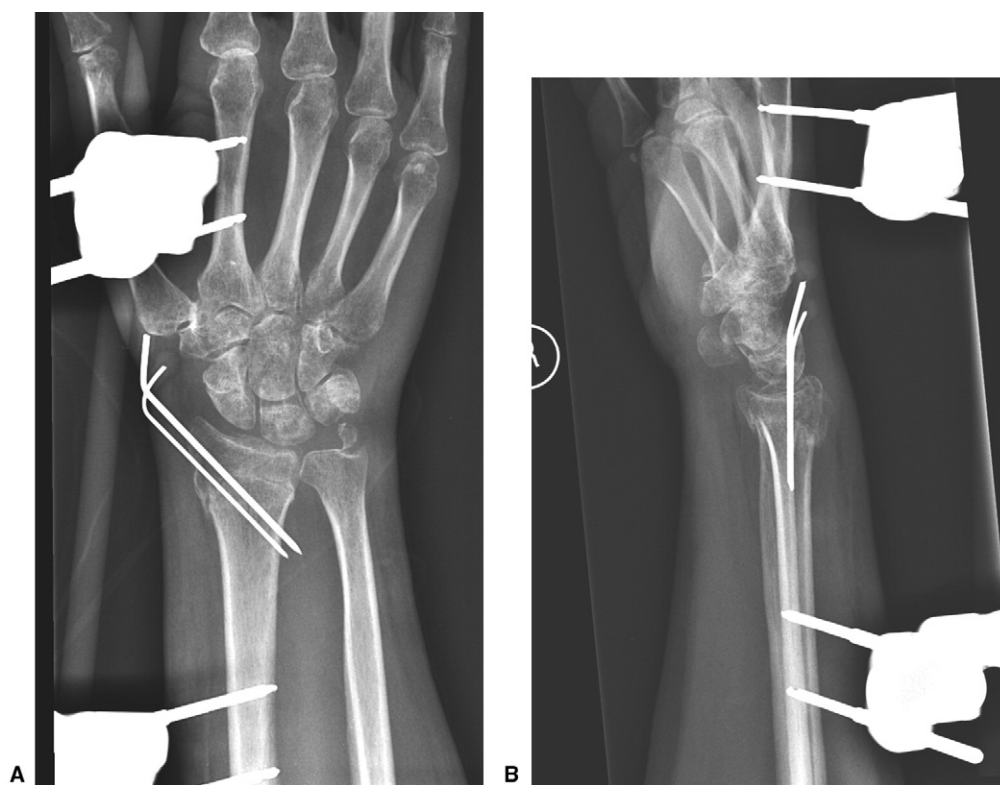


FIGURE 1: **A** Posterior-anterior and **B** lateral x-rays of a typical distal radius fracture treated with spanning external fixation and supplementary percutaneous K-wires. The CHR in this case is 0.60.

and ulnar distal length as referenced to the lunate fossa. We determined CHR^{19,20} by measuring the distance from the distal radius to the base of the third metacarpal and dividing this value by the third metacarpal length. This measure quantifies the amount of distraction across the carpus, with a larger value representing increased distraction. Distal radius volar tilt was defined as a positive angle for volar angulation, and a negative angle for dorsal angulation. Ulnar length was measured from the ulnar head in relation to the lunate facet of the radius, and was positive for a more distal ulna in relation to the distal radius.

Functional outcome evaluation included measurement of wrist ROM, grip strength, and key pinch strength. Overall rating of outcome was assessed by the method previously described by Gartland and Werley,¹⁶ which allowed us to compare our results with previous reports. Return to work status was evaluated in all patients.

Statistical analysis

We evaluated the effects of 2 continuous independent variables, duration of external fixation and CHR at initial reduction, for their effect on clinical outcome and ROM by linear regression methods. These were ana-

lyzed using *t*-tests in relation to the Gartland and Werley outcome ratings. All individual ROM parameters were also analyzed for significant correlations with fixator duration and CHR at placement. We used a significance value of $p < .05$. A power value of greater than 0.8 was used as a goal with a beta error of 0.2 to evaluate the strength of the sample size of the individual data parameters.

RESULTS

After reduction and fixator application, initial radiographic evaluation demonstrated an average carpal height ratio of 0.60 (range, 0.47–0.70), with a volar tilt of 7.7° (range, 21° to –12°), radial inclination of 20.7° (range, 41° to 10°), and an ulnar variance of –0.83 mm (range, 2 to –3 mm). The fractures healed at an average of 7.2 weeks (range, 5–12 weeks) from fixator placement. In the 16 patients for whom adequate follow-up radiographic views were available that demonstrated the entire third metacarpal, the average CHR at the time of fixator removal was 0.54 (range, 0.47–0.65).

Functional rating by the Gartland and Werley evaluation system showed 11 excellent, 10 good, 3 fair, and no poor outcomes, for an 88% rate of good or excellent results. Only 1 patient could not return to work, and 22

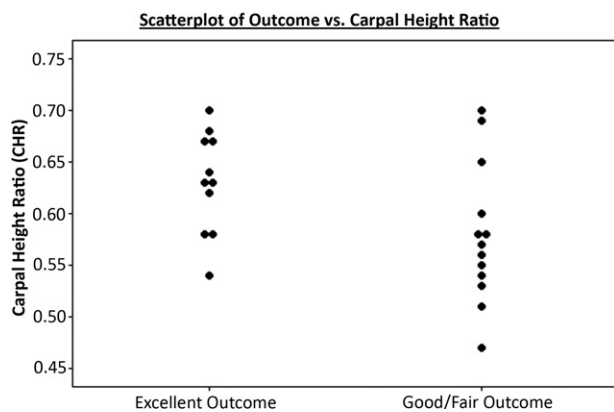


FIGURE 2: Scatterplot of good/fair and excellent outcomes versus CHR. The *t*-test results showed a statistical difference between the mean CHR of the 2 groups at follow-up.

of 24 returned to their preinjury employment. Grip strength averaged 20.4 kg in the affected hand (86% compared with the contralateral side), and pinch strength averaged 8.6 kg (83%). ROM in degrees (and percentage compared with contralateral side) at follow-up was as follows: wrist flexion, 54 (75%); wrist extension, 59 (78%); radial deviation, 18 (85%); ulnar deviation, 22 (73%); pronation, 79 (95%); and supination, 77 (93%). Three patients had superficial pin cellulitis successfully treated with an oral cephalosporin antibiotic. There were no deep pin track infections and no pins had to be replaced. There were no nerve injuries and no cases of reflex sympathetic dystrophy. There was no appreciable loss of reduction during the use of the fixator or after its removal, and all patients tolerated the fixator.

The CHR versus patient outcome was plotted to evaluate differences (Fig. 2). Analysis of the data using a standard *t*-test indicated that the difference in the excellent outcome group versus the good and fair groups showed a significant correlation with increased CHR ($p = .041$). Therefore, this suggests that, within the parameters of CHR studied, a higher CHR is associated with a positive impact on a patient's clinical outcome. Using 0.54 as the standard CHR,¹⁹ we imparted an average of 17% distraction (average CHR = 0.63) in the excellent group, compared with 7% distraction (average CHR = 0.58) in the good and fair group. Table 1 shows the correlation data of increasing CHR and the individual components of ROM. This analysis demonstrates that none of the individual components of motion has a statistically significant correlation with fixator distraction. Only supination ($p = .106$) and ulnar deviation ($p = .138$) at final follow-up had a trend toward a negative correlation with increasing CHR.

TABLE 1. Linear Regression Coefficients (*r*) for Each Plane of Wrist Motion and Associated *p* Values in Relation to Carpal Distraction

Wrist ROM	Increasing CHR	
	<i>r</i>	<i>p</i>
Extension	-0.243	.254
Flexion	-0.063	.771
Radial deviation	-0.071	.749
Ulnar deviation	-0.311	.138
Pronation	-0.200	.351
Supination	-0.338	.106

TABLE 2. Wrist ROM and Duration of External Fixation

Wrist ROM	Increasing Duration	
	<i>r</i>	<i>p</i>
Extension	-0.170	.429
Flexion	-0.179	.405
Radial deviation	-0.152	.475
Ulnar deviation	-0.243	.253
Pronation	-0.118	.581
Supination	-0.138	.518

Linear regression coefficients (*r*) and *p* values are shown.

Power analysis demonstrated that sufficient power (≥ 0.8) was detected in our data set for flexion, pronation, and supination using 10° as a clinically significant difference, for radial deviation with 5° as a significant difference, and for pinch strength using 2.3 kg as a clinically important difference. Power was insufficient for ulnar deviation, extension, and grip strength.

Further analysis demonstrated that there was no negative correlation between any component of active ROM and increasing duration of external fixator at follow-up (Table 2). There was no statistical difference ($p = .891$) between the excellent results group and the good and fair results groups in relation to duration of external fixation (Fig. 3).

DISCUSSION

There have been multiple reports in the literature describing the treatment of distal radius fractures with external fixation. Sanders et al.¹¹ reported on 35 fractures treated with external fixators with a 40% complication rate, including 8 pin track infections and 2 cases



FIGURE 3: Scatterplot of good/fair and excellent outcomes versus duration of external fixation. The *t*-test results showed no statistical difference between groups in relation to fixator duration.

of osteomyelitis. They reported only 68% good or excellent results, as per the Gartland and Werley scoring system. However, 33 of the fractures were stabilized with a quadrilateral frame using a pin in both the second and third metacarpals and the 2 radial shaft pins were placed obliquely from dorsal to volar. There was no mention of amount of distraction, but the patients were first placed in 4.5 kg of traction for 10 minutes, and the external fixator was applied in this position. In addition, 7 patients had a die-punch component to the fracture, which is unlikely to be improved by the distraction provided by the fixator. Final ROM was functional, with average values being: extension, 53°; flexion, 54°; radial deviation, 18°; and ulnar deviation, 30°. These values are comparable to those in our study.

Using a uniplanar external fixator frame with a more standard pin configuration (converging pins with a double row of connecting bars), Edwards⁴ showed excellent or good results in 29 of 30 patients, at an average follow-up of 2.6 years. The fixator was in place for an average of 7.5 weeks, and initial carpal distraction averaged 4 mm. He did not investigate the relationship of fixator distraction or duration with final ROM or functional outcome. The average grip strength was 92% of normal and motion of the wrist and rotation of the forearm averaged more than 90% of the normal side. In this series, complications were rare and there was no loss of fixation of the pins. He attributed his success to the unique converging pin configuration. Average wrist motion was extension, 64°; flexion, 70°; radial deviation, 19°; and ulnar deviation, 27°.

The amount of fixator distraction imparted to the carpus as well as the length of treatment has long been a concern among orthopedists treating these injuries.

Using linear regression analysis, Kaempffe et al.¹³ attempted to analyze the effect of duration and distraction on 26 patients treated with external fixation. Although function, pain, motion, strength, and final grade were negatively correlated with increasing distraction, none of the reported *p* values was significant. The average distraction graded by carpal height ratio was 0.58 (range, 0.49–0.71), which was similar to our study values of 0.60 (range, 0.47–0.70). The duration of fixation was similar, averaging 7 weeks (range, 4–12 weeks). Overall, motion (as graded by the New York Orthopaedic Hospital system) was negatively correlated with external fixation duration at *p* = .006. However, individual components of motion such as flexion and extension were not analyzed. Furthermore, 9 of these patients also had internal fixation using plates for further fracture stabilization. Thus, it is not clear whether the reported effects are from external fixation or the addition of internal fixation. The senior author of that study also published a review paper that included the same data found in the previous study, again warning against the dangers of overdistraction.¹⁴ He also recommended adding supplementary percutaneous wires to the construct to avoid overdistraction, a technique we used often in our study population.

In a more recent study, Kaempffe and Walker¹⁵ reported on 19 patients with distal radius fractures treated with external fixation and supplemental K-wire fixation. The authors stated that the investigation was performed to confirm the previous data, and the team did report similar results. These were severe fractures, with 10 cases being Frykman grade VII or VIII. In that study, again, none of the outcome variables showed statistically significant correlation with increasing distraction. Actually, a positive correlation was found between CHR and eventual wrist motion and radiographic outcome, but these values were not significant. Clinically, the average wrist ROM showed extension at 96%, flexion at 87%, radial deviation at 92%, and ulnar deviation at 81% of the contralateral uninjured wrist. Good to excellent clinical results were reported in 89% of patients and articular congruency (<1-mm stepoff) was restored in 15 patients.

Biyani²¹ reviewed 7 patients with severe distal radius fractures treated with an external fixator applied with increased distraction. Overdistraction was defined as greater than 3-mm space in the radiocarpal and midcarpal joints on the immediate postoperative radiographs. Treatment resulted in 6 good and 1 poor result by the Garland and Werley classification. The 1 poor result had a radiocarpal and midcarpal distraction of 8 mm, and 2 mm of negative ulnar variance. Biyani

concluded that overdistractive is associated with a good outcome, but this may be compromised if the distal radioulnar relationship is altered.

In analysis of our data, there was a statistically significant difference between the excellent results group compared with the good and fair results groups in relation to distraction as measured by the CHR. The mean CHR of the excellent group (0.63) was modestly greater than the mean CHR of the good/fair group (0.58). Thus, we conclude that mildly increased CHR at initial reduction positively correlates with an improved clinical outcome. This may be because this level of distraction holds the intrinsic carpal and extrinsic radiocarpal ligaments out to a functional length and thereby reduces stiffness. Although this level of distraction correlated with a positive outcome, excessive or overdistractive is clearly not helpful. Extreme distraction can induce carpal malalignment, worsen subtle intercarpal ligament injuries, and induce finger stiffness by tightening the extrinsic finger tendons. Similarly, we found no difference in functional outcome associated with duration of fixation within the parameters studied, but we do not recommend excessively prolonging the time in the external fixator. There are threshold limits to the findings in this study that should be observed, and our findings only apply to the reasonable amounts of distraction and duration investigated.

The clinical results obtained in our study compare favorably with the results of studies evaluating the treatment of distal radius fractures treated with volar fixed angle plates. Orbay and Fernandez treated 31 fractures with a volar locked plate, and at a minimum follow-up at 12 months had similar ROM to our study: 59° extension, 57° flexion, 80° pronation, and 78° supination.²² Also, in a comparison study by Wright et al.,² their volar plating group had similar wrist motion values to their external fixation group as well as to our study population.

This distraction does not include excessive palmar flexion or pronation, which makes postoperative therapy and finger ROM difficult and may correlate with a poor functional outcome. Flexion by itself is not effective in restoring distal radius volar tilt because the ligamentous anatomy of the wrist precludes restoration of volar tilt by ligamentotaxis. Bartosh and Saldana demonstrated that the volar tilt may not be restored even with flexing the wrist up to 30°.²³ Appropriate volar tilt can be achieved with palmar translation of the carpus or percutaneous pin fixation, allowing the fixator to be maintained in a functional position.²⁴ Agee reported on this technique in 20 patients treated with an external fixator in neutral alignment and with attention to palmar

translation of the carpus. In addition, supplementary fixation was used in 8 cases. All fractures healed and 95% of patients maintained functional finger motion during treatment.²⁵

Further evidence that wrist immobilization for a sustained time is not detrimental to final ROM is found in reports on the use of a spanning plate across the radial shaft to the metacarpals. Ruch et al.²⁶ evaluated 22 patients with comminuted distal radius fracture treated with a 3.5-mm distraction plate that bypassed the fracture segment, and was fixed to the long or index finger metacarpal distally. The articular surface was anatomically reduced and was secured with supplementary K-wires or screws. The plate was removed after fracture consolidation (at an average of 7.7 weeks), and the wrist motion was initiated. All fractures healed and patients had a final ROM of: flexion, 57°; extension, 65°; pronation, 77°; and supination, 76°. The average Disabilities of the Arm, Shoulder, and Hand scores were 11.5 points at the time of final follow-up (average of 24.8 months). According to the Gartland-Werley rating system, 14 patients had an excellent result, 6 had a good result, and 2 had a fair result. Thus, the use of internal external fixator resulted in good functional results and wrist motion similar to external fixation or open plating. In addition, these fractures were comminuted and more severe than the fractures in our series.

We used only moderate distraction to reduce the fractures in this series. Using 0.54 as the standard CHR,¹⁹ subjects with excellent results had 17% distraction (average CHR, 0.63) and those with good and fair results had 7% distraction (average CHR, 0.58). As a clinical guide, we do not distract the carpus to the point that there is asymmetric widening of either the radiocarpal or midcarpal joints. The average CHR at the time of fixator removal was 0.54 compared with 0.60. This may represent some settling of the external fixator frame after fatigue of the muscle units across the wrist, or measurement error with nonidentical radiographic views as the original radiographs.

In our series, increased distraction at initial reduction was associated with an excellent clinical outcome. However, the average increase in carpal distraction of the excellent results group was only an additional 10% from baseline compared with the good and fair results group. There was no significant loss in wrist ROM with either increasing distraction or increasing duration of external fixation. Our data set had insufficient power to clearly determine if ulnar deviation and supination were negatively associated with carpal distraction. However, the average ulnar deviation at follow-up was 22° and

the supination was 77°, well within functional ROM,²⁷ and thus a clinical difference may not be evident.

Our objective radiographic and functional data, combined with patient subjective reports, demonstrate that external fixation is an acceptable method for treating closed distal radius fractures. We conclude that external fixation of unstable distal radius fractures is not associated with excessive postoperative stiffness, maintains fracture reduction adequately, and is associated with good clinical outcomes. These data have reinforced our practice of using an external fixator when necessary in unstable distal radius fractures, and placing it in neutral position with moderate distraction.

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