# Extra-articular deformity in distal radial fractures treated by external fixation

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**Objective:** To determine the radiographic outcome in fractures of the distal radius treated with closed reduction and external fixation. **Design:** A retrospective study. **Setting:** The orthopedic department of National Taiwan University Hospital. **Patients:** Eighty-five consecutive patients (36 female, 49 male), average age 48 years, with fractures of the distal radius seen between March 1995 and June 1998. **Interventions:** Closed reduction and external fixation of fractures, followed up by good-quality posteroanterior and lateral radiographs to evaluate healing. **Main outcome measures:** Radial height, radial inclination and volar tilt were measured on radiographs obtained initially, immediately postoperatively and at the time of removal of external fixation. Data were analyzed by the *t*-test. **Results:** Immediately after reduction and fixation, there was a significant improvement in the measurements of radial height and radial inclination. This improvement was gradually lost and height and inclination were significantly decreased at the time the external fixation device was removed. External fixation did not improve the volar tilt. **Conclusion:** External fixation is a popular method to improve the reduction of osseous deformity but cannot effectively protect comminuted distal radial fractures from loss of reduction, which may be associated with shortening and redisplacement.

**Objectif :** Déterminer le résultat radiographique dans les cas de fractures du radius à la partie distale traitées par réduction orthopédique et fixation externe. **Conception :** Étude rétrospective. **Contexte :** Département d'orthopédie de l'hôpital de l'Université nationale de Taiwan. **Patients :** Quatre-vingt-cinq patients consécutifs (36 femmes, 49 hommes), qui avaient en moyenne 48 ans et qui ont subi une fracture à la partie distale du radius entre mars 1995 et juin 1998. **Interventions :** Réduction orthopédique et fixation externe des fractures, suivies de radiographies postéroantérieures et latérales de bonne qualité pour évaluer la guérison. **Principales mesures de résultats :** On a mesuré la hauteur radiale, l'inclinaison radiale et l'inclinaison du bord antérieur du radius au moyen de radiographies obtenues au début, immédiatement après l'intervention et au moment de l'enlèvement de la fixation externe. On a analysé les données au moyen du test-*t*. **Résultats :** Immédiatement après la réduction et la fixation, on a constaté une amélioration importante des mesures de la hauteur radiale et de l'inclinaison radiale. Cette amélioration a disparu graduellement et la hauteur et l'inclinaison avaient diminué considérablement au moment où l'on a enlevé l'appareil de fixation externe. La fixation externe n'a pas amélioré l'inclinaison du bord antérieur du radius. **Conclusion :** La fixation externe est une méthode populaire utilisée pour améliorer la réduction des déformations osseuses, mais elle ne peut protéger efficacement les fractures comminutives du radius à la partie distale contre une perte de réduction, qui est sans doute attribuable au raccourcissement et au redéplacement.

Fracture of the distal radius is one of the most common orthopedic injuries. Unique among periarticular and intra-articular fractures, the standard of treatment for most distal radial fractures has been closed reduction and immobilization.[1] It is widely believed that deformity does not correlate with functional limitation. The injury is predominant in the elderly, often with concomitant medical problems, low functional demands and significant osteoporosis.[1] Recently, because of motor vehicle accidents and recreational activities, there

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has been an increase in the number of high-energy fractures of the distal radius seen in young adults, resulting in documentation of the surgical management of these injuries.[2]

During the past 20 years evidence has been provided that function is intimately related to both the intra-articular and extra-articular malunion formed in distal radial fractures.[2] Extra-articular and intra-articular malunion have both been shown in the laboratory[3,4] and in clinical studies,[5,6] to alter function and the patient's satisfaction with treatment outcome. Restoration of normal alignment and articular congruity after a displaced fracture can be difficult but is essential for a good functional result.[7,8]

Conventional open techniques introduce additional surgical trauma, and incision of important capsular and ligamentous structures may be associated with a high complication rate.[9,10] The results of closed reduction, percutaneous pin fixation, pin in cast, and internal and external fixation[9,11–14] have been variable and have been determined largely by the pattern of the fracture.[15] Closed reduction and casting or closed reduction and external fixation as a treatment option alone suffers from the inability to manipulate displaced or depressed articular fragments.[5,16] Percutaneous pinning has been recommended as an adjunct to reduce and maintain difficult articular fragments. This technique misses associated soft-tissue and ligamentous injuries, which are being recognized with increasing frequency.[17,18] The purpose of this study was to determine the radiographic outcomes of acute fracture of the distal radius, treated with close reduction and external fixation.

## Materials and methods

### *Study design*

This was a retrospective study of consecutive patients having distal radial fractures treated by close reduction and external fixation at one institution who were followed up until the fracture was united and the fixation device removed. The study design included the evaluation of plain radiographs made at the patient's initial visit, immediate postoperatively and at the time of removal of external fixation.

### *Patients*

Between March 1995 and June 1998, 85 consecutive patients (36 female, 49 male) with 85 distal radial fractures were treated by external fixation in the orthopedic department of National Taiwan University Hospital. Five surgeons were responsible for fixation. Patients who had received open reduction and internal fixation with plate and screws, who had undergone closed reduction and cast immobilization or who had associated multiple injuries were excluded from the study. Patients were also excluded if either the posteroanterior or the lateral perioperative radiograph was unavailable. The mean age at the time of the injury was 48 years (range from 13 to 87 years). The mean (and standard deviation [SD]) ages were 53.7 (20.2) years for female patients and 44.4 (20.0) years for male patients. Fifty-two fractures occurred on the left side and 33 fractures occurred on the right (Table 1).

### *Classification of fractures*

All fractures were classified according to the Association for Osteosynthesis (AO) and Association for the Study of Internal Fixation systems,[19] with use of posteroanterior and lateral radiographs of the wrist made at the time of the initial injury and after the reduction. According to this classification, 2 fractures were type A1, 5 were type A2, 6 were type A3, 2 were type B2, 21 were type B3, 14 were type C1, 21 were type C2, and 14 were type C3.

### *Operative treatment*

Overall, closed reduction and external fixation were performed a mean (and SD) of 3.1 (4.5) days (range from 0 to 22 days) after the injury. Six patients, initially managed in the emergency department with closed reduction followed by immobilization in an above-the-elbow plaster cast, were operated on between 9 and 22 days after injury. The external fixation devices used to maintain axial stability included the following: AO type external fixation (Marthys Medical, Davos, Switzerland), 28 patients; and Richards type external fixation (3M Health Care Group, St. Paul, Minn.), 57 patients. All operations were performed under

**Table 1**

**Clinical Data for 85 Patients Having Distal Radial Fractures Treated by Closed Reduction and External Fixation**

| Data | No. of patients |
|---|---|
| Age, yr | |
| 11–20 | 13 |
| 21–30 | 7 |
| 31–40 | 9 |
| 41–50 | 12 |
| 51–60 | 18 |
| 61–70 | 15 |
| 71–80 | 5 |
| 81–90 | 6 |
| Side of fracture | |
| Left | 52 |
| Right | 33 |
| Time to operation, d | |
| 0 | 6 |
| 1 | 37 |
| 2 | 14 |
| 3 | 5 |
| 4 | 6 |
| 5 | 9 |
| 6 | 0 |
| 7 | 2 |
| >7 | 6 |
| Time to removal of external fixation device, d | |
| 38–42 | 19 |
| 43–49 | 27 |
| 49–56 | 20 |
| 57–63 | 9 |
| > 63 | 10 |

Raw clinical data may be obtained from the author.

fluoroscopic surveillance, and when the intra-articular fragments could not be reduced satisfactorily or when there was obvious fracture instability, supplementary Kirschner wire fixation was applied. All of these wires were independent and not incorporated onto the external fixator frame. In this series, 27 fractures required no supplementary Kirschner wire fixation, 24 fractures required 1 Kirschner wire, 27 fractures required 2 Kirschner wires, 4 fractures required 3 Kirschner wires and 3 fractures required 4 Kirschner wires. The external fixation frame was removed at a mean (and SD) of 51.2 (12.0) days (range from 38 to 101 days).

### *Imaging evaluation*

Good-quality posteroanterior (PA) and lateral radiographs were obtained for evaluating the distal radial fractures. The PA view was taken by abducting the patient's humerus so that the elbow was at the same level as the shoulder. The lateral view was taken with the humerus adducted and the elbow flexed at 90°. Two radiographic measurements were routinely recorded in regard to displacement of the distal radius. All imaging studies were assessed in a blinded fashion by 2 independent investigators, and the 2 measurements were averaged. When measurements varied by more than 50%, the 2 observers simultaneously re-evaluated the imaging study, and a third consensus measurement was made. In the PA view, radial height and inclination were routinely recorded. The radial height was the distance between 2 lines perpendicular to the long axis of the radius, one drawn at the tip of the radial styloid and another drawn at the distal ulnar articular surface. Radial inclination was the angle formed between a line drawn through the tip of the radial styloid and the medial corner of the lunate facet and a line drawn perpendicular to the long axis of the radius. In the lateral view, the volar tilt of the distal radial articular surface was measured.[20–22] To study the stabilizing effect of the method of external fixation, standardized radiographic controls were obtained with posteroanterior and lateral views at 2 stages of treatment (immediately postoperatively and at the time external fixation was removed) plus the original films before reduction. For each patient, 3 radiographs were available.

### *Analysis of the data*

The differences between various measurements were evaluated by Student's *t*-test. Statistical significance was defined as $p < 0.05$.

## Results

### *Radiographic evaluation*

Osseous deformity of the distal aspect of the radius was assessed by the radial height, radial inclination and volar tilt at the different stages of treatment. Radial height was improved at the initial preoperative stage but the reduction was lost at the time the external fixation device was removed and was only minimally better than initially. Likewise the radial inclination was improved at the immediate postoperative radiographic evaluation but had decreased by the time of removal of external fixation (Table 2, $p < 0.05$ for all comparisons). The volar tilt of the distal radius improved from an average of –1.26° (16.17°) to an average of 0.94° (11.35°) at the immediate postoperative evaluation, then remained stationary at 0.95° (11.87°) at the time external fixation was removed. No significant difference was noted between the initial visit before reduction, immediately postoperatively and after removal of the external fixation device (Table 2, $p > 0.05$ for all comparisons).

### *Supplementary Kirchner wire fixation*

In order to evaluate whether supplementary Kirchner wires will improve the stabilization of external fixation, the differences in the immediately postoperative and preoperative (IP–Preop.) measurements, removal of the implant and preoperative (ROI–Preop.) and removal of the implant and immediately postoperative (ROI–IP) were analyzed. The results showed that the addition of Kirchner wires did not improve the stabilization effect ($p > 0.05$, Table 3).

### *Degree of comminution*

The degree of comminution of the distal radius did not affect the correction effect of radial length and radial inclination but did affect the correction of volar tilting (Table 4). For the correction of volar tilting, fractures with less comminution (i.e., type 1) received more correction after application of external fixation both in the measurements IP–Preop. and ROI–Preop. (Table 4). External fixation did not effectively protect the less comminuted fractures from loss of reduction in the ROI–IP period (Table 4).

**Table 2**

**Distal Radial Measurements at the 3 Intervals as Determined From the Radiographs***

| Measurement interval | Radial height, cm | | Radial inclination, ° | | Volar tilt, ° | |
|---|---|---|---|---|---|---|
| | Mean | SD | Mean | SD | Mean | SD |
| Preop | 8.71 | 2.75 | 17.51 | 5.44 | –1.26 | 16.17 |
| IP | 11.30 | 2.46 | 22.77 | 4.94 | 0.94 | 11.35 |
| ROI | 9.71 | 2.67 | 19.61 | 5.04 | 0.59 | 11.87 |

IP = immediately postoperatively, ROI = removal of implant, SD = standard deviation.
*Differences between Preop and IP, between Preop and ROI, and between IP and ROI for radial height and inclination were significant, $p < 0.05$, but differences for volar tilt were not significant, $p > 0.05$. Raw data for the $p$ values can be obtained from the author.

## Discussion

Evidence has shown that in distal radial fractures function is intimately related to the radiographic findings.[2] Extra-articular and intra-articular malunion have both been shown to alter function and patient satisfaction with the outcome of treatment. Although considerable improvement has been achieved, the management of fractures of the distal radius still presents important problems, especially with respect to new, sophisticated techniques of external fixation.[23,24] Evidence in the literature indicates a strong correlation between restoration of bone anatomy and recovery of function.[25] At present, the most efficient and innocuous method of reduction is gentle, prolonged longitudinal traction applied to the relaxed upper limb after adequate anesthesia.[12] The crucial problem remains how to stabilize these fractures until they become well united. The purpose of this study was to describe the stabilization effect on fractures of the distal radius by the external fixation device.

As we have noted, the osseous deformity of the distal aspect of the radius showed significant improvement in measurements of radial length and inclination immediately after reduction (Table 2). Despite this, the restoration of volar tilting of the distal radius was not well achieved with external fixation (Table 2). The strong palmar ligaments have been shown to become taut and limit radiocarpal distraction, while the weaker, Z-shaped dorsal ligament complex has yet to reach maximum length.[26] This prevents longitudinal traction alone from restoring volar tilt and may explain why the volar tilt of the distal radius deformity did not improve significantly with external fixation (Table 2). The failure of longitudinal traction to restore palmar slope and radiocarpal alignment in some injuries must be recognized at the time the external fixation device is placed.

The periarticular soft tissues (i.e., the capsular, ligamentous and tenoretinacular structures enveloping the distal fragments) help to keep them in the reduced position. Such soft-tissue support is an important point for stabilizing the fracture. For distal radial fractures, a high frequency of ligamentous injuries is commonly associated with both intra-articular and extra-articular fractures.[27] The plain radiographs were probably inadequate to identify acute ligamentous injuries. Even if no ligamentous injuries existed coincidentally and the distal radial fractures were well reduced at the time of initial management, the stretched ligaments will gradually become deformed and the stress relaxed, followed by redisplacement of well-reduced fractures. In this study, the reduction in the measurements of radial length and inclination were grad-

**Table 3**

**Effects of Kirschner Wire (K wire) Supplementation on the Correction in Distal Radial Measurements**

| Difference in measurement | Radial height, cm | | | Radial inclination, ° | | | Volar tilt, ° | | |
|---|---|---|---|---|---|---|---|---|---|
| | Mean | SD | *p* value | Mean | SD | *p* value | Mean | SD | *p* value |
| IP–Preop | | | 0.08 | | | 0.11 | | | 0.26 |
| Without K wire | 1.98 | 2.69 | | 4.11 | 6.06 | | 0.66 | 16.32 | |
| With K wire | 2.88 | 2.64 | | 5.80 | 5.55 | | 2.92 | 12.60 | |
| ROI–Preop | | | 0.24 | | | 0.14 | | | 0.28 |
| Without K wire | 0.70 | 2.55 | | 1.15 | 5.14 | | 0.65 | 12.70 | |
| With K wire | 1.14 | 2.92 | | 2.55 | 6.09 | | 2.42 | 12.54 | |
| ROI–IP | | | 0.13 | | | 0.37 | | | 0.41 |
| Without K wire | –1.28 | 1.64 | | –2.97 | 3.55 | | –0.01 | 9.73 | |
| With K wire | –1.74 | 1.90 | | –3.25 | 3.84 | | –0.51 | 7.09 | |

IP = immediately postoperatively, ROI = removal of implant.

**Table 4**

**Effects of Degrees of Comminution on Correction in Distal Radial Measurements**

| Difference in measurement/degree of comminution | Radial height, cm | | | Radial inclination, ° | | | Volar tilt, ° | | |
|---|---|---|---|---|---|---|---|---|---|
| | Mean | SD | p value | Mean | SD | p value | Mean | SD | p value |
| IP–Preop | | | *p* 1–2 = 0.47 | | | *p* 1–2 = 0.33 | | | ***p* 1–2 = 0.035** |
| Type 1 | 2.75 | 2.55 | *p* 2–3 = 0.26 | 5.24 | 6.06 | *p* 2–3 = 0.17 | 10.16 | 13.33 | *p* 2–3 = 0.12 |
| Type 2 | 2.80 | 2.18 | *p* 1–3 = 0.33 | 6.06 | 5.28 | *p* 1–3 = 0.39 | 2.63 | 11.82 | ***p* 1–3 = 0.004** |
| Type 3 | 2.39 | 3.05 | | 4.73 | 5.98 | | –1.19 | 14.26 | |
| ROI–Preop | | | *p* 1–2 = 0.36 | | | *p* 1–2 = 0.49 | | | ***p* 1–2 = 0.052** |
| Type 1 | 1.38 | 1.92 | *p* 2–3 = 0.27 | 2.44 | 4.14 | *p* 2–3 = 0.30 | 8.36 | 12.09 | *p* 2–3 = 0.09 |
| Type 2 | 1.16 | 1.96 | *p* 1–3 = 0.20 | 2.47 | 4.46 | *p* 1–3 = 0.32 | 2.57 | 8.66 | ***p* 1–3 = 0.007** |
| Type 3 | 0.74 | 3.51 | | 1.73 | 7.13 | | –1.17 | 14.09 | |
| ROI–IP | | | *p* 1–2 = 0.28 | | | *p* 1–2 = 0.22 | | | *p* 1–2 = 0.19 |
| Type 1 | –1.38 | 1.41 | *p* 2–3 = 0.50 | –2.80 | 3.01 | *p* 2–3 = 0.26 | –1.81 | 3.93 | *p* 2–3 = 0.48 |
| Type 2 | –1.64 | 1.59 | *p* 1–3 = 0.29 | –3.59 | 3.45 | *p* 1–3 = 0.42 | –0.06 | 9.23 | *p* 1–3 = 0.33 |
| Type 3 | –1.65 | 2.13 | | –3.01 | 4.20 | | 0.02 | 8.31 | |

IP = immediately postoperatively, ROI = removal of implant.
Type 1, *n* = 16, type 2, *n* = 28, type 3, *n* = 41.
*p* 1–2 = *p* value for differences between types 1 and 2, *p* 2–3 = *p* value for differences between types 2 and 3, *p* 1–3 = *p* value for differences between types 1 and 3.

ually lost and had decreased significantly by the time the external fixation device was removed (Table 2). This corresponded to the viscoelastic characteristics of ligaments.[28,29]

It had been reported that supplementary Kirchner wires in the distal fragment permit the surgeon to exactly reposition fracture fragments. It avoids the need to depend on ligamentotaxis to restore or maintain volar tilt.[22,30,31] The results of this study showed that the addition of a Kirchner wire did not improve the stabilization effect of external fixation (Table 3). It meant that fixation with multiple Kirchner wires does not reliably maintain the reduced position even in younger patients[32,33] and is inappropriate in older patients with osteoporosis.[34]

Some important factors that should be considered when evaluating distal radial fractures are the degree and location of comminution. These factors were vital to predicting the outcome of management. Severe dorsal comminution is associated with shortening and redisplacement, whereas a volar butterfly fragment may be associated with median neurapraxia.[35] We found that the degrees of comminution in distal radial fractures treated by external fixation did not affect the correction effect of radial length and radial inclination but did affect the correction effect of volar tilting (Table 4). Fractures with less comminution got more correction after application of external fixation. The external fixation cannot effectively protect less comminuted fractures from loss of reduction (Table 4).

## Conclusions

Malunion of distal radial fractures is correlated with a poor functional outcome. Additionally, soft-tissue, intercarpal ligament and distal radioulnar joint disruption further worsens outcome. The position of the fracture at the time of union rather than the position at the time of presentation has the greatest correlation with long-term functional results. Although residual articular malalignment may be better tolerated in older patients who sustain lower energy injuries, the longer lifespan and increased activity of our growing elderly population heightens the importance of anatomic articular restoration. External fixation is a popular method that may improve the reduction of osseous deformity but cannot assure the maintenance of reduction. The high rate of ligamentous injuries indicated that the poorly regained volar tilt of the distal radius must be restored. Reduction of distal radial fractures cannot be achieved and maintained reliably using external fixation alone.

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