Internal Fixation of Pilon Fractures of the Distal Radius

Thomas E. Trumble, M.D.*, Susan R. Schmitt, M.D., and Nicholas B. Vedder, M.D

Harborview Medical Center, University of Washington School of Medicine, Seattle, Washington 98195

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When closed manipulation fails to restore articular congruity in comminuted, displaced fractures of the distal radius, open reduction and internal fixation is required. Results of surgical stabilization and articular reconstruction of these injuries are reviewed in this retrospective study of 49 patients with 52 displaced, intra-articular distal radius fractures.

Forty-three patients (87%) with a mean age of 37 years (range of 17 to 79 years) were available for evaluation. The mean follow-up time was 38 months (range 22–69 months) When rated according to the Association for the Study of Internal Fixation (ASIF), 19 were type C2 and 21 were type C3. We devised an Injury Score System based on the initial injury radiographs to classify severely comminuted intra-articular fractures and to identify those associated with carpal injury (3 patients).

Post-operative fracture alignment, articular congruity, and radial length were significantly improved following surgery ($p < .01$) Grip strength averaged 69% ± 22% of the contralateral side, and the range of motion averaged 75% ± 18% of the contralateral side post-operatively. A combined outcome rating system that included grip strength, range of motion, and pain relief averaged 76% ± 19% of the contralateral side. There was a statistically significant decrease in the combined rating with more severe fracture patterns as defined by the ASIF system ($p < .01$), Malone classification ($p < .03$), and the Injury Score System ($p < .001$). The Injury Score System presented here, and in particular the number of fracture fragments, correlated most closely with outcome of all the classification systems studied.

Operative treatment of these distal radius fractures with reconstruction of the articular congruity and correction of the articular surface alignment with internal fixation and/or external fixation, can significantly improve the radiographic alignment and functional outcome. Furthermore, the degree to which articular stepoff, gap between fragments, and radial shortening are improved by surgery is strongly correlated with improved outcome, even when the results are corrected for severity of initial injury, whereas correction of radial tilt or dorsal tilt did not correlate with improved outcome.

INTRODUCTION

The decisions involved in treating a patient with complex distal radius fractures with articular involvement are often difficult because there are a wide variety of options. Surgical treatment of distal radius fractures is demanding, and the potential complications are significant. Several studies indicate that restoring the articular congruity of these complex distal radius fractures will provide a good clinical result and limit the risk of post-traumatic arthrosis [1, 2, 3, 4]. Cooney et al. [5] suggested that open reduction

*To whom correspondence should be addressed. Department of Orthopaedics, RK-10, University of Washington, Seattle, WA, 98195.

†Abbreviations used: ASIF, Association for the Study of Internal Fixation.
and internal fixation with restoration of the articular surface is necessary for patients with widely displaced, intra-articular fractures because of the likelihood of loss of reduction and inability to re-establish joint congruity with closed treatment. Specific guidelines regarding the indications for open reduction and the timing of surgery were not outline. Knirk and Jupiter [6] provided anecdotal evidence that patients with a residual intra-articular step-off of more than 2 mm had a poor functional outcome. Although the numbers were too small for statistical correlation, they recommended a 2-mm step-off as an indication for surgery and as a goal operative reduction.

The current classification systems which include both extra-articular and intra-articular patterns, lead to some confusion when addressing treatment options and predicting the prognosis of displaced, intra-articular, comminuted fractures. The Frykman classification [7] does not consider the deforming forces, nor does it incorporate significant factors of radiocarpal articular incongruity. The ASIF® system [8] differentiates complex intra-articular fractures from less comminuted intra-articular fractures and from extra-articular fractures. Malone’s classification [4] provides insight into the mechanism of injury and focuses on the intra-articular fracture as a separate entity. Information concerning the complexity of the fracture, the pattern of displacement, as well as injuries to the carpus, would be useful in providing insight into management and ultimate prognosis.

A variety of surgical treatments have been recommended. These variable results and treatment recommendations are perplexing in part because the authors included ASIF C1 fractures which have a minimally displaced fracture extending into the articular surface along with ASIF C2 and C3 The C1 fractures can often be treated as extra-articular fractures. Malone indicated that certain type 4 fractures were best treated with open reduction and internal fixation [4]. Howard et al. noted good results with closed manipulation and external fixation alone [9]. Lueng et al. [10] suggested that bone grafting and external fixation alone provided excellent results. Seitz recommended external fixation and a limited open reduction [11] that presumably exposed the fracture site but did not open the radiocarpal joint. Bone grafting was used in 18% of these fractures. In one of the most comprehensive reviews of various surgical options, Fernandez [3] contends that a variety of techniques are necessary depending on the fracture pattern. The results vary depending on the percentage of C1 fractures included in the study (if indeed it is even noted). Bradway et al. [2] reported 81% good to excellent results; Fernandez and Gessler [3] reported 5% radiocarpal arthritis; Leung [10] reported that nearly all the patients in his study had excellent results. Seitz et al. observed that 82% of the patients had a satisfactory result, but they did not mention the objective data used to assess satisfactory and unsatisfactory results. Fernandez and Gessler felt that there was a direct correlation between radiographic results and the subjective and functional outcome but the statistical significance was not evaluated [3].

The patient results that are rated by outcome measures that rely heavily on radiographic results add to the confusion of treating patients with intra-articular distal radius fractures. In most of these studies, the radiographic parameters are improved post-reduction, and this can overshadow less promising functional results determined by upper extremity motion, grip strength, and pain relief. The wide age range of the patients studied may influence the rating system as well. Finally, without comparisons to the contralateral uninjured hand, it is difficult to normalize the results to compare one study to another.

To better understand surgical treatment of displaced intra-articular distal radius fractures, we reviewed 43 patients, all of whom had ASIF type C2 and C3 distal fractures of the distal radius. All were treated with open reduction and internal/external fixation. The technique varied depending on the fracture pattern. The purpose of this study was three-
fold: 1) to critically examine the efficacy of surgery in correcting these factors, 2) to determine which factors are most important to correct in order to maximize functional outcome, and 3) to objectively identify the fracture-related factors affecting functional outcome.

**MATERIALS AND METHODS**

Between 1987 and 1990, 49 consecutive patients with pilon fractures of the distal radius were treated at Harborview Medical Center and the University of Washington Medical Center. Forty-three of these patients were available for follow-up examination by the treating physician, a local physician or a hand therapist. The mean age of the patients was 37 years with a range of 17-79 years. The mean time to follow-up was 29.3 months with a range of 13-60 months. The right side was involved in 22 cases, and the dominant hand was involved in 23 cases.

**Pre-operative radiographic evaluation**

All patients had pre-operative antero-posterior, oblique, and lateral radiographs. In many of the initial injury films, the fractures were either poorly aligned (especially in the multiple trauma patients) or had substantial overlap of fragments preventing accurate measurements. Therefore, the initial post-reduction films were used for radiographic measurements. The loss of articular congruity of the distal radius was measured as a gap (mm) when there was a diastasis, or as a step-off (mm) when one fragment was proximal or distal to the adjacent fragment. The largest apparent gap or step-off was recorded.

While recognizing that these measurements do not represent the initial displacement of the fracture, they are much more reproducible and practical than the initial injury films. The length of the radius relative to the ulna was determined using the technique for patient positioning and radiographic measurement as described by Palmer et al. [13] for ulnar variance. The radial tilt and palmar tilt were measured according to standard guidelines [6].

**Post-operative evaluation**

Antero-posterior and lateral radiographs of both wrists were obtained at the follow-up examinations. The radial shortening was determined by subtracting the ulnar variance of the injured wrist from the contralateral wrist. This measurement was reported as positive millimeters of radius shortening. Using a comparison to contralateral radiographs, allowed the radial and palmar tilt to be reported as a percentage of the contralateral side. Two patients had a fracture of the contralateral radius, but both were minimally displaced fractures and did not affect the comparative measurements. The palmar tilt, assessed from the lateral radiographs, was determined to be 0° when the distal radius articular surface was perpendicular to the shaft of the radius. When the articular surface had a palmar tilt from the perpendicular, the measurement was reported as positive degrees of angulation. When the surface had a dorsal tilt, it was reported as negative degrees of angulation.

**Fracture classification**

All fractures were rated by the ASIF, Malone’s, and Frykman’s classifications. In addition, we developed an Injury Score System to help predict the functional results based on the initial injury radiographs. This system assigns one point for each fracture fragment displaced by more than 1 mm, and an additional point for concurrent carpal injury.
Treatment algorithm

All patients with isolated trauma were initially treated by closed reduction with local anesthetic and plaster splint immobilization in the emergency room (except for patients with a depressed central segment in whom closed reduction was not attempted). An initial closed reduction was performed even when it was obvious that internal fixation would be necessary because this maneuver improved patient comfort pre-operatively, minimized radius shortening, and improved visualization of the fracture fragments. Our protocol avoided multiple attempts at closed reduction when it was obvious that reconstruction of the articular surface was necessary. Multiple trauma patients were treated with closed reduction and plaster splinting while life threatening injuries were addressed.

Pre-operative tomograms were obtained as needed to facilitate surgical planning. A surgical plan was formulated based on the following: displacement of the carpus and the fracture fragments, loss of the dorsal or volar rim of the articular surfaces, loss of the buttressing effects of the volar or dorsal metaphyseal bone, depression of articular fragments, and the need for bone grafting to support depressed fragments. The patients' initial treatment was determined in the following criteria for intra-articular fractures (Figure 1).

A. Simple extra-articular fracture/simple intra-articular fracture

Patients with a minimally displaced intra-articular fracture and extra-articular fracture without metaphyseal comminution. Patients with this type of injury can be treated in a closed fashion with cast immobilization.

B. Metaphyseal comminution of extra-articular fracture/simple intra-articular fracture:

Patients with an unstable extra-articular fracture due to metaphyseal comminution but a stable, minimally displaced intra-articular fracture pattern, were treated with application of an external fixator with or without percutaneous Kirschner wires.

C. Simple extra-articular fracture/comminuted intra-articular fracture:

Patients with a stable extra-articular fracture without comminution and an unstable displaced articular fracture were treated by open reduction and internal fixation.

Figure 1. Intra-articular can be divided into patterns by the treatment required. 1A. Simple extra-articular fracture/simple intra-articular fracture: treatment = cast immobilization. 1B. Metaphyseal comminution of extra-articular fracture/simple intra-articular fracture: treatment = external fixation. 1C. Simple extra-articular fracture/comminuted intra-articular fracture: treatment = open reduction and internal fixation. 1D. Metaphyseal comminution of extra-articular fracture/comminuted intra-articular fracture: treatment = open reduction and internal fixation with supplemental external fixation.
Fracture D. Metaphyseal comminution of extra-articular fracture/on comminuted intra-articular fracture

These unstable fractures were treated by open reduction, internal fixation, bone grafting and the application of an external fixation device.

Surgical Approach

The surgical approach depended on the type of injury:

| Deforming Force                      | Surgical Approach |
|--------------------------------------|-------------------|
| dorsal fracture/dislocation          | dorsal            |
| volar fracture/dislocation           | volar             |
| axial loading injuries               | dorsal            |
| complex fractures                    | dorsal and volar  |

Surgical technique

Dorsal fracture dislocations are approached through a longitudinal incision over the third dorsal compartment. The extensor pollicis longus sheath is released and the tendon retracted radially. Sharp dissection is used to define the plane between the fourth compartment and the dorsal wrist capsule. This helps decrease the formation of adhesions from the extensor tendons to the dorsal retinaculum. No repair of the retinaculum is necessary, and bow stringing of the extensor digitorum communis and the indicis proprius is not encountered. Bow stringing of the extensor pollicis longus during wrist extension has not been a functional problem. The radiocarpal joint is exposed by incising the dorsal radiotriquetral ligament close to the dorsal rim of the distal radius. Care is taken to avoid opening the capsule of the distal radialulnar joint.

Volar fracture dislocations were exposed through either a Henry’s approach or an extended carpal tunnel release. When the significant articular injury was at the scaphoid fossa, the radius was accessed through a distal Henry’s approach. If the articular injury primarily involved the lunate fossa, a carpal tunnel release-type incision, extending across the distal wrist crease was preferred. This allowed adequate exposure of this segment of the distal radius.

Fractures with loss of the volar or dorsal buttressing metaphysis were treated with an external fixator to maintain length; and internal fixation with Kirschner wires (K wires), lag screws, and buttress plates to align and support the articular fragments. Frequently the external fixation was needed for only a few weeks, particularly when bone graft was used. Fractures without involvement of the metaphyseal buttress could be treated by open reduction and internal fixation alone.

The bone grafts were obtained from the iliac crest or the olecraneon depending on the volume anticipated and whether the patient would require platform crutches in cases where the patient had concomitant lower extremity injuries.

The technique of internal fixation varied depending on the comminution and the quality of the bone fragments. Comminuted fractures involving the dorsal or volar rim of the radius in patients with osteoporotic bone were treated with Kirschner wires and a buttress plate applied dorsally or volarly. Patients with normal bone density and large fracture fragments were ideal candidates for lag screw fixation with 3.5 mm screws. As our experience increased, we used bone graft with more regularity. The amount of bone loss/size of gaps and a trend of fracture healing with less collapse leads us to recommend
bone grafting for nearly all of these fractures.

Post-operative treatment

All patients were initially immobilized in a long-arm coaptation plaster (sugar tong) splint as this permitted swelling after surgery and minimized problems of pain and nerve compression post-operatively. The day following surgery patients were started on finger exercises particularly stressing flexion of the metacarpophalangeal joints. One week after the surgery the long-arm splint was removed and patients were divided into treatment categories, depending on the stability of their fracture patterns and the type of fracture fixation.

- Patients with external fixation devices were started on a pronation/supination program with a supportive volar splint. Finger exercises are stressed. Because of the rapid fracture consolidation when bone graft was used, the external fixation device was usually removed four weeks after surgery. All external fixation devices are removed within six weeks after surgery. Once these devices were removed, the patient used a removable splint to start wrist range-of-motion exercises.

- Patients with minimal comminution and large fracture fragments that permitted secure internal fixation (the definition of secure internal fixation is clearly a judgment for the operating surgeon): We feel that in this group protection with a splint is needed primarily to prevent re-injury. One to two weeks following surgery the patient mainly performs active range-of-motion exercises with a removable splint. Four to five weeks after surgery, passive range-of-motion exercises are added after confirming that the fracture pattern has remained stable and is healing, based on radiographs.

- Patients with extensive fracture comminution and/or osteoporosis: but not requiring external fixation. These are patients whom the surgeon judges still need some form of external support. The patient is placed in a short-arm cast to begin pronation and supination exercises, as well as digit range-of-motion exercises. The cast is bi-valved four weeks after surgery in order to start wrist range-of-motion exercises. These are done as active exercises for the first two weeks and then advanced to passive range-of-motion exercises. If the patients have a residual deficit of pronation or supination at six weeks following surgery, they are placed into a long-arm splint that has a dynamic component to increase the pronation and supination. This device has been extremely helpful in gaining an additional 20–30° of rotation in the direction that has been restricted following the surgery.

Grip strength, range-of-motion, and pain

Functional evaluation: At the time of follow up, range-of-motion was measured (dorsiflexion, palmar flexion, radial and ulnar deviation, pronation and supination) in both hands. Grip strength was measured using a Jamar Adjustable Dynamometer (Jas. P. Marsh Corporation; Skokie, Illinois.) Range-of-motion and grip strength are reported as a percentage of the uninjured to the contralateral side. Three patients had contralateral injuries, and their measurements were not included in the statistical analysis.

Evaluation of post operative pain: A relief of pain rating was based on the following scale:

| Scale | Description |
|-------|-------------|
| 100   | no pain with activity |
| 90    | some discomfort but without limitation in activities |
| 80    | discomfort during performance of heavy labor activities or stressful daily living without requiring occupational or lifestyle changes |
70 discomfort/pain prohibiting return to previous occupation, but
not light recreational activities or activities of daily living
60 discomfort/pain occasionally during even light recreational activities
that does not preclude these activities or activities of daily living
50 pain with all activities noted above and occasionally with simple activities of daily living, but not to a limiting extent
40 pain that inhibits some simple activities of daily living
30 symptoms as noted above that can be relieved with an immobilizing splint
20 symptoms requiring splinting and medication
10 symptoms requiring splinting, medication and rest to relieve pain
0 unrelenting pain

Analysis of data
Student's t test, multivariate, and univariate regression analysis were used to determine the levels of statistical significance.

RESULTS

Surgical technique
Thirty-seven subjects had a dorsal approach only. Five subjects had a volar approach. One subject had a combined dorsal and volar approach. Nine subjects had Kirschner wire fixation. Twenty-two had a buttress plate. Twenty-nine (67%) fractures

Figure 2. A. Severely comminuted fracture of the articular surface with loss of metaphyseal buttressing is complicated by scapholunate dissociation. B. Treatment included ORIF with K-wires, buttress plate and external fixation. The carpal instability was treated with ORIF.
were treated with bone grafting. The thirty-four patients with simple extra-articular/comminuted intra-articular fractures were treated with internal fixation, with or without bone graft, whereas the nine patients with comminution of extra-articular/comminuted intra-articular fractures had external fixation to supplement the internal fixation. Four patients with severely comminuted fractures with loss of the buttressing metaphysis were treated with combined external fixation, buttress plating, K-wire fixation, and bone graft. Those with carpal injuries required stabilization of the carpus as well (Figure 2A, B)

Radiographic results

The radiographic parameters all improved following open reduction and internal fixation. The loss of radial tilt (RT) improved from $5.5^\circ \pm 5.1^\circ$ to $0.9^\circ \pm 1.5^\circ$ and the loss of palmar tilt (PT) improved from $15.2^\circ \pm 13.7^\circ$ to $3.7^\circ \pm 4.9^\circ$. The correction in the combined angular deformity was from $20.7^\circ \pm 18.1^\circ$ pre-operatively, to $4.6^\circ \pm 5.4^\circ$ post-operatively. The surgery also helped to restore the articular congruity. The pre-operative fracture gap averaged $3.0 \pm 13$ mm compared to $0.5 \pm 0.7$ mm post-operatively. The pre-operative step-off decreased from $2.5 \pm 1.0$ mm to $0.0 \pm 0.5$ mm, post-operatively. This resulted in an improvement in total incongruency from $5.5$ mm $\pm 2.0$ to $0.5 \pm 1$ mm.

Paired $t$ test demonstrated that all angular and articular deformities were significantly improved post-operatively. The mean improvement in step-off was $2.5$ mm ($p < 0.001$); gap $2.0$ mm ($p < 0.001$); radial shortening $1.0$ mm ($p < 0.001$); radial tilt $4.7^\circ$ ($p < 0.001$); and palmar tilt $11.4^\circ$ ($p < 0.001$).

Associated injuries

Eleven subjects had associated injuries. Three of these had a contralateral fracture, paralysis, or both. Two subjects had additional carpal injury, had a lunate fracture and triangular fibrocartilage complex avulsion, and another patient had a scapholunate separation with scaphoid articular damage.

Complications

There were two pin tract infections which were successfully treated with pin removal and oral antibiotics. One patient had a late rupture of the extensor pollicis longus. This was treated with transfer of the extensor indicis proprius to the extensor pollicis longus with excellent functional recovery. One patient had severe post traumatic arthritis. This patient had the largest pre-operative gap and total pre-operative incongruity, in addition to the largest total incongruency post-operatively. He had persistent pain, and eleven months post-operatively, tomograms confirmed the presence of degenerative changes in the radiocarpal joint. He was the only patient who required wrist arthrodesis.

Functional results

The total arc-of-motion compared to the contralateral side averaged $74.7\% \pm 18.3\%$. The grip strength averaged $69\% \pm 22\%$ of the contralateral side. When the patients were questioned about fatigue, there was a substantial difference in that the injured side subjectively tended to fatigue more quickly and have a decrease in grip strength after long periods of work. The average pain relief activity level was $84 \pm 20$. There was no significant difference between the results of patients who required external fixation and those who did not require external fixation The average combined functional rating was $76\% \pm 19\%$. Activities that were noted to be restricted were those which required maximum dorsiflexion palmarflexion. The high number of serious associated injuries and the length of disability made it difficult to assess the impact that the distal radius fracture had on restricting the patient’s ability to return to his or her original occupation.
Predicting outcome based on injury patterns

Fracture classification as predictor of outcome: There was a strong correlation between increasing degree of injury as classified by ASIF, Malone, and Injury Score System, and a decrease in the combined functional rating. (ASIF, \( p < 0.01 \), Malone, \( p < 0.03 \), and Injury Score System, \( p < 0.0001 \), using simple regression analysis.) The Frykman classification did not show significant correlation (\( p > 0.08 \)) between increasing severity of injury and the functional outcome. The Injury Score System had adequate numbers in each group to demonstrate significant differences between groups. Of all of the classification systems examined, the Injury Score System showed the best correlation with functional outcome. If the fracture involved four or more fragments, the combined functional rating decreased to approximately 70% (Figure 3).

Pre-operative radiographic changes: By regression analysis, neither the palmar nor radial tilt deformities separately or in combination correlated significantly with the functional outcome. Nor did the pre-operative gap in the articular surface (mean 2.5 ± 1.5 mm) correlate with functional outcome (\( p > 0.1 \)). Pre-operative step-off (mean 2.5 ± 1.0 mm), radial shortening (mean 1.5 ± 1.5 mm), and total incongruity (mean 5.5 ± 2.0 mm), however, did correlate with functional outcome (\( p < 0.05 \). Of these, total incongruity (pre-operative step-off plus pre-operative gap) showed the closest correlation (\( p < 0.02 \)).

Functional outcome as a result of treatment

Neither post-operative residual loss of palmar tilt (3.7 ± 5.0°) nor post-operative residual loss of radial tilt (0.9 ± 1.6°) correlated with functional outcome. However, post-operative gap (0.5 ± 0.5 mm; \( p < 0.0001 \)), post-operative step-off (0.0 ± 0.5 mm; \( p < 0.0002 \)), total incongruity (0.5 ± 1.0 mm; \( p < 0.0001 \)), and post-operative radial shortening (0.5 ± 0.5 mm; \( p < 0.002 \)) all closely correlated with the functional outcome. This was true even when the results were corrected for the severity of initial injury (by including injury score in a multiple regression analysis). Of these factors, total incongruity (pre-operative step-off plus pre-operative gap) showed the closest correlation (\( p < 0.02 \)).

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Y = 119.2 - 11.1 \times X; \quad R^2 = .4
\]

Figure 3. The average Combined Functional Result decreased with increasing number of fracture fragments present.
Gruity correlated most closely with functional outcome (Figure 4). The most important single factor was post operative gap between fragments (Figure 5). Patient age did not correlate with functional outcome.

**Figure 4.** There was a significant correlation between the total post-operative incongruity (combined measurement of the articular step-off and gap in mm) and the functional rating. The patients with less total incongruity of the distal radius had better functional results based on the Combined Functional Rating.

**Figure 5.** The patients with smaller gaps in the articular surface of the distal radius post-operatively had better functional results by the combined rating system. A substantial decrease in the patient's functional results occurred when the residual gap on post-operative radiographs was greater than 1.0 mm.
DISCUSSION

This data suggests that operative intervention can improve the radiographic alignment and that correction of articular step-off and gap (total incongruity) play important roles in the ultimate functional outcome. Interestingly, correction of radial tilt and palmar tilt do not appear to be as important.

Based on this study, we concur with the recommendations of Fernandez and Geissler to aggressively treat intra-articular distal radius fractures that have a total incongruity (sum of step-off plus gap between fragments) of greater than 1 mm using a variety of surgical techniques currently available, including open reduction and internal fixation with pins, screws, plates, external fixation, and bone grafting, depending on the pattern of injury. As our experience increased, we noted that bone graft improved the quality of reduction and seemed to correlate with earlier callus formation. We could not investigate this statistically. The overriding goal should be to restore the articular congruity and maintain length in an attempt to optimize functional outcome. Any residual articular incongruity will severely compromise functional outcome.

The Malone and ASIF classifications, as well as the Injury Score System that we present here, appear to be useful in predicting the prognosis and functional outcome when evaluating these complex fractures. It seems reasonable to suggest that these fractures should be classified apart from distal radius fractures in which the articular surface is not involved or is non-displaced.

A limitation to this review is the short follow-up time. To rate conclusively the ultimate disabilities in these patients, a longer follow-up period will be required. Nevertheless, one would expect that long-term outcome would continue to deteriorate in those patients whose articular congruity was not corrected, further strengthening our conclusions.

Open reduction

We propose treating these injuries based on the stability and comminution of the intra-articular and extra-articular components in addition to the mechanism of injury (dorsal/volar fracture dislocation or impaction injury). Comparisons between studies is extremely difficult when the fracture classification used does not reflect the amount of articular displacement. Many studies showing good results with intra-articular fractures using internal fixation involve a large number of patients that have ASIF C1 fractures which could have been managed by external fixation. These are in effect similar to the unstable extra-articular fractures [14, 13, 15, 9, 16]. These injuries are distinctly different from the ASIF C2 and C3 fractures that have displaced segments of the distal radius articular cartilage despite attempted closed reduction. Knirk and Jupiter pointed out that these patients will have an increased risk of degenerative arthritis due to the loss of articular congruity [6]. Open reduction and internal fixation is indicated in this situation to restore the articular surface of the radius. There are a growing number of reports demonstrating good results with open reduction and internal fixation, occasionally with the addition of bone grafts and external fixation [1, 2, 3, 6, 10, 11]. External fixation, although it prevents early wrist motion, does provide the stability to allow immediate pronation and supination as well as facilitating digit motion that can be restricted by bulky casts. In our experience, open reduction and internal fixation offers the best long term result for patients who have displaced intra-articular fractures despite an initial attempt at closed reduction.

Radiographic evaluation

Using radiographs of the contralateral extremity allows a more accurate assessment
of the angular deformity and articular congruity. This is also the only way to accurately assess the amount of radial shortening. Although other reports of internal fixation for distal radius fractures have demonstrated an improvement in angular deformity, our study demonstrates an improvement of both the angular deformity as well as articular congruity. These results may explain why classification systems, such as the one devised by Frykman, which do not evaluate articular incongruency, cannot predict outcomes [1, 2, 3, 10, 22].

As noted by Knirk and Jupiter [6], we found no statistical correlation between post-operative angular deformity and functional outcome; however, there was a strong correlation with the functional result between the post-operative step-off, gap, and especially total incongruity. One report has indicated that extreme angular deformities correlate with abnormal loadbearing in the wrist [23] but the residual post-operative malalignment in our study was less than the 20° malalignment used in the biomechanical study.

Patient population

The patients in this study were younger on average than in many other studies [2, 10, 12, 21, 24]. Many of our patients had multiple trauma from high energy injuries which decreased our threshold for operative intervention. Even the older patients in our study were quite active and had substantial high energy injuries. We recommend internal fixation when necessary to re-establish the articular congruity even in these patients and do not hesitate to use an external fixator in patients with osteoporotic bone. There was no correlation between the patient's age and functional outcome.

Complications

Two patients had minor pin tract problems and one patient had a tendon rupture secondary to a prominent pin. There were no cases of reflex sympathetic dystrophy or post-operative carpal tunnel syndrome. Only one patient required carpal tunnel release at the time of internal fixation. We attribute the absence of these complications to our policy of avoiding multiple, unsuccessful closed reductions and our technique of applying only enough distraction with external fixation devices to displace the carpus 1-2 mm distally from the radius. All Kirschner wires were cut short and buried beneath the skin. All external fixators were removed by the sixth post-operative week which decreased the risk of pin track problems.

Based on this study, we recommend viewing displaced intra-articular fractures as a separate group and classifying them according to the extent of fragmentation and related injuries. In most young patients and active elderly patients, a residual total articular incongruity greater than 1 mm following closed reduction should be treated with open reduction and internal fixation using a technique based on the pattern of fracture, the extent of comminution and the presence or absence of osteoporosis.

REFERENCES

1. Axelrod, T. S and McMurtry, R. Y. Open reduction and internal fixation of comminuted, intra-articular fractures of the distal radius J. Hand Surg. 15-A:1–11, 1990.
2. Bradway, J. K., Amadio, P. C., and Cooney, W. L. Open reduction and internal fixation of displaced, comminuted intra-articular fractures of the distal end of the radius. J. Bone and Joint Surg. 839–847, 1989.
3. Fernandez, D. L. and Geissler, W. B. Treatment of displaced articular fractures of the radius. J. Hand Surg. 375–383, 1991.
4. Malone, C. P., Jr. Articular fractures of the distal radius. Clin. Orthop. North America, 15:17–236, 1984.
5. Cooney, W. P., III, Linscheid, R. L., and Dobyns, J. H. External pin fixation for unstable colles fractures. J. Bone and Joint Surg. 61-A:840–845, 1979.
6. Knirk, J. L. and Jupiter, J. B. Intra-articular fractures of the distal end of the radius in young
24. Frykman, G. Fracture of the Distal Radius Including Sequelae-Shoulder-Hand-Finger Syndrome. Disturbances in the Distal Radial-Ulnar Joint, and Impairment of Nerve Function. A Clinical and Experimental Study. Acta Orthop. Scandinavica, Supplementum 108,1-153, 1967.

8. Muller, ME.; Nazarian, S.: and Koch, P.: Classification AO des Fractures. Les Os Longs. Berlin, Springer, 1987.

9. Howard, PW, Stewart HD: Hind, RE, and Burke, FD: External Fixation or Plaster for Severely Displaced Comminuted Colles Fractures? A Prospective Study of Anatomical and Functional results. J. Bone and Joint Surg. 71-B: 68–73, 1989.

10. Leung, K. S., Shen, W. Y. Tsang, F. M., Leung, P. C., and Hung, L. K. An effective treatment of comminuted fractures of the distal radius. J. Hand Surg. 15-A:11–17, 1990.

11. Seitz, W. H., Jr., Froimson, A. L, Leb, R. and Shapiro, J. D. Augmented external fixation of unstable distal radius fractures. J. Hand Surg. 16-A:1010–1016, 1991.

12. Axelrod, T. S. and McMurtry, R. Y. Limited open reduction of the lunate facet in comminuted intra-articular fractures of the radius. J. Hand Surg. 13A:643–658. DATE?

13. Palmer, A. K., Glisson, R. R., and Werner, F. W. Ulnar variance determination. J. Hand Surg. 7:376–379, 1982.

14. Edwards, G. S. Intra-articular fractures of the distal part of the radius treated with small AO external fixator. J. of Bone and Joint Surg. 73A:1241–1250, 1991.

15. Gainar, B. J. and Groh, G. I. Early clinical experience with orthofix external fixation of complex distal radius fractures. Orthopaedics. 13:329–333, 1990.

16. Szabo, R. M. and Weber, S. C. Comminuted intra-articular fractures of the distal radius. Clin. Orthop. 230:39–48, 1988.

17. Gartland, J. J. and Werley, C. W. Evaluation of healed colles fractures. J. Bone and Joint Surg. 33A:895–907, 1951.

18. Green, D. P. Pins and plaster treatment of comminuted fractures of the radius. J. Bone and Joint Surgery 57A:304–310, 1975.

19. Green, D. P. and O'Brien, E. T. Open reduction of carpal dislocations. Indications and operative techniques. J. Hand Surg. 3:250–265, 1978.

20. Sarmiento, A., Pratt, G. W., Bwur, N. C., and Sinclair, W. F. Colles fractures, functional bracing in supination. J. Bone and Joint Surg. 57A:311, 1975.

21. Hohresh, Z., Volpin, G., Hoerer, D., Stein, ?, The surgical treatment of severe comminuted fractures of the distal radius with a small AO external fixation device. Clin. Orthop. and Related Research 263:147–153, 1991.

22. Jupiter, J. B. Current concepts review- fractures of the distal end of the radius. J. Bone and Joint Surgery 73-A:461–467, 1991.

23. Pogue, D. J., Viegas, S. F., Pattersen, R. M., Petersen, P. D., Jenkins, D. K., Sweo, T. D. and Hokansen, J. A. Effects of distal radius fracture malunion on wrist joint mechanics. J. Hand Surg. 15A:721-727 1990.

24. Jenkins, N. H. The unstable colles fracture. Jour. of Hand Surg. 14B:149–154, 1989.