Functional Outcomes for Unstable Distal Radial Fractures Treated with Open Reduction and Internal Fixation or Closed Reduction and Percutaneous Fixation. A Prospective Randomized Trial

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Functional Outcomes for Unstable Distal Radial Fractures Treated with Open Reduction and Internal Fixation or Closed Reduction and Percutaneous Fixation

A Prospective Randomized Trial

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Background: Despite the recent trend toward internal fixation of distal radial fractures, few randomized trials have examined whether volar plate fixation is superior to other stabilization techniques. The purpose of the present study was to compare (1) open reduction and internal fixation with use of a volar plate and early mobilization with (2) percutaneous fixation and casting or external fixation for the treatment of dorsally displaced unstable extra-articular and simple intra-articular fractures of the distal part of the radius, with a specific emphasis on early functional recovery.

Methods: A prospective randomized study was performed at two institutions. Forty-five consecutive patients with a displaced, unstable fracture of the distal part of the radius were randomized to closed reduction and pin fixation (n = 22) or open reduction and internal fixation with a volar plate (n = 23). Clinical and radiographic assessments were conducted at six, nine, and twelve weeks after surgery and at one year. Outcome was measured on the basis of range of motion; grip and pinch strength; and Disabilities of the Arm, Shoulder and Hand scores. A questionnaire was used to determine patient satisfaction, and a detailed analysis of complications was performed.

Results: Patients in the open reduction and internal fixation group had superior Disabilities of the Arm, Shoulder and Hand scores at six, nine, and twelve weeks. At six weeks, the average Disabilities of the Arm, Shoulder and Hand score was 27 in the open reduction and internal fixation group as compared with 53 in the closed reduction and pin fixation group ($p < 0.01$). At nine and twelve weeks, patients in the open reduction and internal fixation group continued to have lower scores (17 compared with 39 [$p < 0.01$] and 11 compared with 26 [$p = 0.01$], respectively). At one year, there was no significant difference between the two groups in terms of the Disabilities of the Arm, Shoulder and Hand scores. Patients in the open reduction and internal fixation group had greater range of motion and strength than patients in the closed reduction and pin fixation group at six and nine weeks, and more patients in the open reduction and internal fixation group were very satisfied with the overall wrist function and motion. Eight complications occurred, two in the open reduction and internal fixation group and six in the closed reduction and pin fixation group.

Conclusions: Both closed reduction with percutaneous pin fixation and open reduction with internal fixation with use of a volar plate are effective methods for the treatment of dorsally displaced, unstable, extra-articular or simple intra-articular fractures of the distal part of the radius. Better functional results can be expected in the early postoperative period in association with open reduction and internal fixation, and this form of treatment should be considered for patients requiring a faster return to function after the injury.

Level of Evidence: Therapeutic Level I. See Instructions to Authors for a complete description of levels of evidence.

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Distal radial fractures represent >300,000 injuries in the United States per year and are the most common fracture of the upper extremity[1]. Anatomic reduction with stable fixation has long been the treatment of choice for displaced, unstable fractures[2]. Closed reduction with percutaneous pin fixation and/or external fixation have historically been the most common treatment methods for unstable injuries[3-8]. More recently, open reduction and internal fixation has gained popularity, particularly with the advent of volar locking plate technology[9]. Advocates have suggested that internal fixation allows immediate range of motion of the wrist while maintaining alignment, resulting in a rapid functional recovery[10-12].

Although several case series have documented excellent outcomes following open reduction and internal fixation with volar plate fixation for the treatment of unstable fractures[13-16], few randomized trials have been carried out to further examine whether this treatment method is superior to traditional pin fixation techniques[17-19]. The purpose of the present study was to compare (1) open reduction and internal fixation with use of a volar plate and early mobilization with (2) percutaneous fixation and casting or external fixation for the treatment of dorsally displaced unstable extra-articular and simple intra-articular fractures of the distal part of the radius, with a specific emphasis on early functional recovery.

Materials and Methods

The trial was conducted across two tertiary care institutions, the Beth Israel Deaconess Medical Center and Brigham and Women's Hospital in Boston, Massachusetts. The study was approved by the institutional review board of both participating hospitals. This clinical trial was registered under ClinicalTrials.gov (NCT00828685).

Consecutive patients presenting to the outpatient orthopaedic clinic with dorsally displaced fractures of the distal part of the radius were eligible for inclusion in the study. The inclusion criteria and surgical indications are summarized in Table I.

Between February 2006 and September 2007, 374 patients with distal radial fractures were assessed in our clinic and were evaluated for eligibility. Of these, 322 did not meet inclusion criteria and seven refused to participate. Thus, forty-five consecutive patients met the inclusion criteria and agreed to participate in the study. The study group included thirty-four women and eleven men with an average age of fifty-one years (range, nineteen to seventy-nine years). The mechanism of injury was a fall from a standing height in forty-three cases and a fall from a ladder in two cases. The fractures were classified according to the AO classification system[2]. There were sixteen type-A fractures (including six type-A2 fractures and ten type-A3 fractures) and twenty-nine type-C fractures (including eight type-C1 fractures and twenty-one type-C2 fractures with a single intra-articular split). The operative criteria were dorsal angulation in thirty-one patients; dorsal angulation and loss of apposition in five; dorsal angulation and radial shortening in six; dorsal angulation and articular incongruity in one; and dorsal angulation, loss of apposition, and shortening in two. These determinations were made on standard radiographs, and no comparison radiographs of the contralateral extremity were made.

Patients were randomized with the aid of a computer-generated list. Simple randomization was used, and patients

TABLE I Inclusion and Exclusion Criteria

Inclusion Criteria	Exclusion Criteria
Age ≥18 years	Multiple trauma or other injuries
Independent function	Patients who rely on others for basic activities
Dorsally displaced, extra-articular fracture	Volarly displaced fractures (Smith and AO type-B fractures)
Simple intra-articular fracture with a single split between the scaphoid and lunate facets	Complex articular fractures with more than a sagittal split between the scaphoid and lunate facets or articular depression
Isolated injury	Open fractures
Substantial initial displacement, inadequate initial reduction, or loss of reduction within 3 weeks after injury as defined by one or more of the following:	Fractures associated with neurovascular injury
>20° of dorsal angulation of the articular surface on the lateral radiographic view	Fractures associated with injuries that will inhibit the ability to participate in a structured rehabilitation program
>100% loss of apposition	Associated musculoskeletal injuries to the same arm
>5 mm of shortening by ulnar variance on the posteroanterior radiographic view	Inflammatory arthritis
Both dorsal and volar comminution	

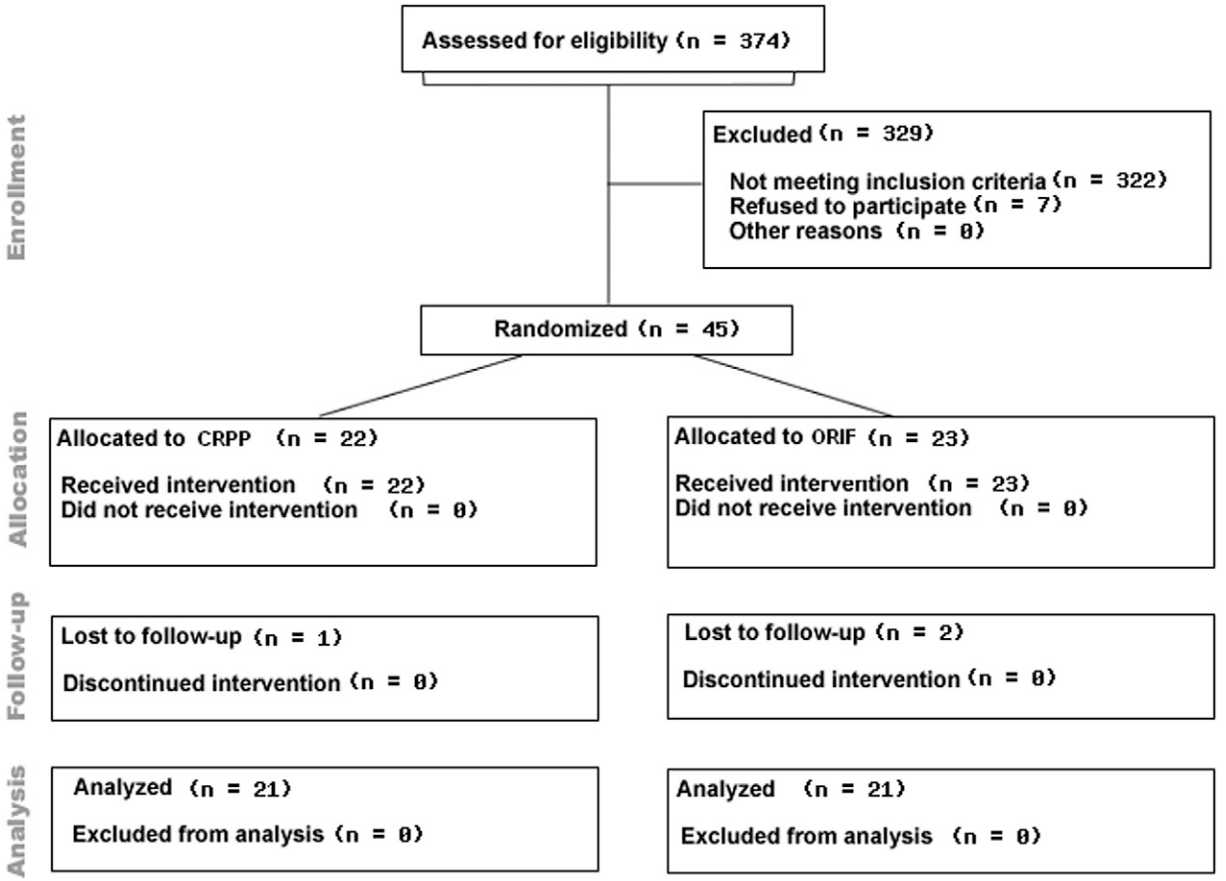

Fig. 1

Flow diagram for enrollment and analysis. CRPP = closed reduction and percutaneous pin fixation, and ORIF = open reduction and internal fixation.

were assigned to either Group 1 (closed reduction with percutaneous pin fixation) or Group 2 (open reduction and internal fixation). One randomization list was used for both participating centers. Numbers were placed in sealed envelopes and were opened at the time of intervention. Twenty-two patients were randomized to closed reduction with percutaneous pin fixation, and twenty-three were randomized to open reduction and internal fixation with a volar plate. All surgical procedures were performed within two weeks after the injury.

One patient in the closed reduction and percutaneous pin fixation group had development of distal radioulnar joint instability and required closed reduction and pin fixation at six weeks postoperatively. One patient in the open reduction and internal fixation group had acute distal radioulnar joint instability and underwent an open repair of the triangular fibrocartilage complex at the time of the index procedure. A second patient in the open reduction and internal fixation group sustained a refracture at the initial site after a fall down a flight of stairs and underwent repeat open reduction and internal fixation four weeks postoperatively. These patients were included in the final analysis. One patient in the closed reduction and percutaneous pin fixation group sustained a second fracture (involving the olecranon) in the early postoperative period and required hospitalization. She was subsequently lost to follow-up.

At six, nine, and twelve weeks, all but one of the patients were available for follow-up; the one patient who was unavailable was from the closed reduction and percutaneous pin fixation group. At one year, two patients in the open reduction and internal fixation group were lost to follow-up, leaving forty-two patients (93%) available for final evaluation. The two patients in the open reduction and internal fixation group who were lost to follow-up in the late postoperative period were included in the analysis at six, nine, and twelve weeks but were excluded from the analysis at one year. All outcomes were analyzed according to intent-to-treat principles, whereby patients are included in the group to which they were initially randomly assigned, regardless of the final treatment received. The flow diagram for this trial is summarized in Figure 1.

Group Comparison

The open reduction and internal fixation group and the closed reduction with percutaneous pin fixation group were compared to ensure that the patients had similar demographic characteristics. No difference was detected between the groups with regard to age ($p = 0.76$), sex ($p = 0.38$), or involvement of

TABLE II Demographic Characteristics*

	Open Reduction and Internal Fixation	Closed Reduction and Percutaneous Pin Fixation
Age† *(yr)*	51 (19 to 77)	52 (24 to 79)
Sex‡		
Female	16 (70%)	17 (81%)
Male	7 (30%)	4 (19%)
Hand dominance‡		
Right	18 (78%)	20 (95%)
Left	5 (22%)	1 (5%)
Dominant extremity fractured‡	9 (39%)	7 (33%)
AO fracture classification‡		
A2	2 (9%)	4 (19%)
A3	8 (35%)	2 (10%)
C1	2 (9%)	6 (29%)
C2	11 (48%)	9 (43%)

*One patient in the closed reduction and percutaneous pin fixation group was lost to follow-up before six weeks. The totals in the table represent the twenty-three patients in the open reduction and internal fixation group and the twenty-one remaining patients in the closed reduction and percutaneous pin fixation group. †The values are given as the average, with the range in parentheses. ‡The values are given as the number of patients, with the percentage in parentheses.

the dominant extremity (p = 0.69). No differences were detected in terms of fracture severity, except that there were more type-A3 fractures in the open reduction and internal fixation group. The individual characteristics for each group are summarized in Table II.

Technique

The surgical technique for the closed reduction and percutaneous pin fixation group involved a closed reduction under fluoroscopic guidance with ligamentotaxis. Once anatomic alignment was achieved, a 1.6-mm Kirschner wire was placed through a small stab incision obliquely through the radial styloid. Two additional wires were placed in a similar fashion along the ulnar aspect of the distal part of the radius. Two patients with severe osteoporosis and extensive extra-articular comminution required external fixation for added stability (Synthes, Paoli, Pennsylvania [n = 1] and Stryker, Kalamazoo, Michigan [n = 1]). Postoperatively, the wrist was immobilized in a volar plaster splint. Active and passive finger motion was encouraged early in the postoperative period. One week after surgery, patients were transitioned to a short-arm cast until fracture-healing. Following cast and pin removal at six weeks, the patients were referred for outpatient occupational therapy with use of a standardized active and passive range-of-motion protocol. Patients managed with supplemental external fixation were not managed with a short-arm cast. The external fixators and pins were removed at six weeks, and the patients were referred to occupational therapy for the same therapy protocol.

Open reduction and internal fixation was performed with use of a volar approach through the flexor carpi radialis tendon sheath. The distal and radial borders of the pronator quadratus were elevated, and the volar aspect of the radius was exposed subperiosteally. The plate was placed directly on the radius following fracture reduction, and plate placement was confirmed with intraoperative fluoroscopy. After fixation, the pronator quadratus was reattached to its radial insertion. Definitive fracture stabilization was achieved with use of VLS plates (Wright Medical, Arlington, Tennessee) (n = 20) and DVR plates (Hand Innovations, Warsaw, Indiana) (n = 3). The operating surgeons (T.D.R., P.E.B., B.E.E., and C.S.D.) determined the choice of implant. Bone-grafting was not performed. Postoperatively, the wrist was immobilized in a volar plaster splint. Patients were instructed in active and passive finger motion. One week after surgery, the patients were placed in a custom-made Orthoplast volar splint and were referred to occupational therapy for an early range-of-motion protocol.

All surgical procedures were performed by one of four fellowship-trained hand and upper extremity surgeons (T.D.R., P.E.B., B.E.E., and C.S.D.).

Outcomes

All available patients were assessed clinically and radiographically in the early postoperative period (at one week to ten days) and then at six, nine, and twelve weeks as well as twelve months after surgery. At each visit, a directed clinical examination was performed by an independent examiner (A.T.C.), who was a research assistant in the Department of Orthopaedic Surgery. Prior to the initiation of the study, the independent examiner received extensive training from an occupational therapist in how to perform the required range-of-motion and grip-strength measurements. The independent examiner was not made aware of the treatment arm to which the patient had been randomized, but no masking was used to cover the patients' wounds.

Range of motion of the wrist was evaluated by recording flexion-extension, pronation-supination, and radioulnar deviation with a standard goniometer. Digital motion was measured for each finger and was tabulated as the distance from the finger pad to the distal palmar crease. Grip and pinch strength was measured with a dynamometer (Sammons Preston, Bolingbrook, Illinois), and the values were compared with those for the contralateral extremity.

Anteroposterior, lateral, and oblique radiographs were made at each visit. Union of the fracture was defined as osseous bridging across the fracture site as seen on two of the three views. Delayed union was defined as healing that occurred six months or more after the injury. Radial height, radial inclination, and volar tilt were measured in the immediate postoperative period (ten days after surgery) and at the time of the

TABLE III Clinical Outcomes

Clinical Outcome	Open Reduction and Internal Fixation	Closed Reduction and Percutaneous Pin Fixation	P Value*
6 weeks			
Flexion† *(deg)*	50 ± 12	26 ± 16	**<0.01**
Extension† *(deg)*	45 ± 20	16 ± 13	**<0.01**
Supination† *(deg)*	79 ± 21	40 ± 29	**<0.01**
Pronation† *(deg)*	77 ± 17	63 ± 26	**0.04**
Ulnar deviation† *(deg)*	27 ± 10	15 ± 11	**<0.01**
Radial deviation† *(deg)*	15 ± 7	7 ± 6	**<0.01**
Grip strength‡ *(kg)*	22 (21%)	12 (30%)	**<0.01**
Pinch strength‡ *(kg)*	27 (26%)	18 (27%)	**0.01**
Digital motion to palm† *(mm)*	0.1 ± 0.4	0.1 ± 0.4	0.81
DASH score† *(points)*	27 ± 17	53 ± 28	**<0.01**
9 weeks			
Flexion† *(deg)*	56 ± 13	41 ± 14	**<0.01**
Extension† *(deg)*	54 ± 14	37 ± 16	**<0.01**
Supination† *(deg)*	81 ± 15	59 ± 28	**<0.01**
Pronation† *(deg)*	86 ± 9	84 ± 9	0.58
Ulnar deviation† *(deg)*	32 ± 7	21 ± 9	**<0.01**
Radial deviation† *(deg)*	17 ± 7	14 ± 9	0.17
Grip strength‡ *(kg)*	28 (18%)	17 (24%)	**<0.01**
Pinch strength‡ *(kg)*	33 (17%)	25 (25%)	**0.01**
Digital motion to palm† *(mm)*	0 ± 0	0.1 ± 0.7	0.33
DASH score† *(points)*	17 ± 17	39 ± 25	**<0.01**
12 weeks			
Flexion† *(deg)*	58 ± 13	55 ± 19	0.51
Extension† *(deg)*	58 ± 14	48 ± 18	0.06
Supination† *(deg)*	84 ± 13	72 ± 26	0.06
Pronation† *(deg)*	85 ± 11	80 ± 20	0.29
Ulnar deviation† *(deg)*	35 ± 6	30 ± 8	**0.02**
Radial deviation† *(deg)*	22 ± 9	20 ± 10	0.55
Grip strength‡ *(kg)*	29 (19%)	32 (63%)	0.92
Pinch strength‡ *(kg)*	38 (17%)	34 (22%)	0.23
Digital motion to palm† *(mm)*	0 ± 0	0 ± 0	—
DASH score† *(points)*	11 ± 13	26 ± 23	**0.01**
1 year			
Flexion† *(deg)*	68 ± 14	72 ± 15	0.42
Extension† *(deg)*	64 ± 17	66 ± 20	0.69
Supination† *(deg)*	88 ± 5	87 ± 9	0.55
Pronation† *(deg)*	88 ± 4	88 ± 4	0.68
Ulnar deviation† *(deg)*	40 ± 11	32 ± 7	**0.01**
Radial deviation† *(deg)*	28 ± 15	22 ± 10	0.11
Grip strength‡ *(kg)*	40 (19%)	41 (60%)	0.57
Pinch strength‡ *(kg)*	44 (40%)	40 (27%)	0.35
Digital motion to palm† *(mm)*	0 ± 0	0 ± 0	—
DASH score† *(points)*	4 ± 8	9 ± 18	0.18

*Significant values are denoted in bold. †The values are given as the mean and the standard deviation. ‡The values are given as the mean, with the percentage of the value for the uninjured side in parentheses.

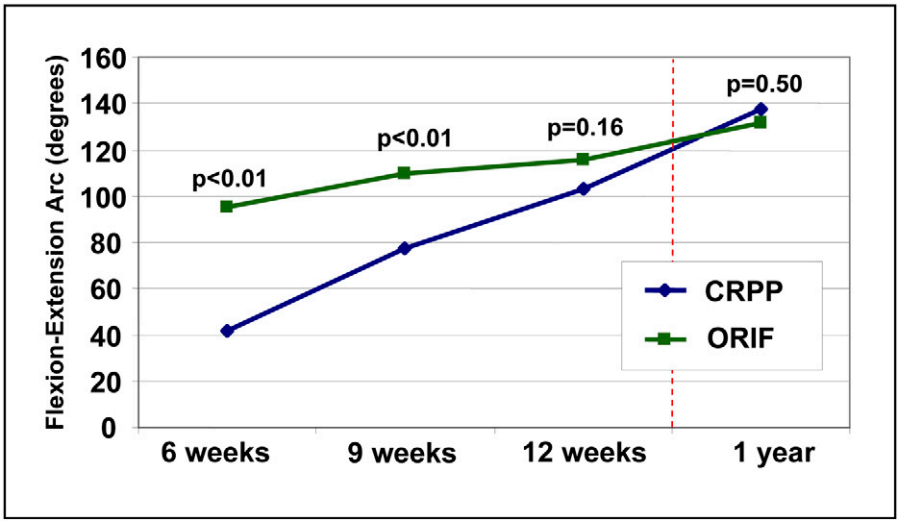

Fig. 2

Line graph illustrating the mean flexion-extension arc for both groups. Patients managed with open reduction and internal fixation (ORIF) had better range of motion in the early postoperative period. CRPP = closed reduction and percutaneous pin fixation.

latest follow-up (one year after treatment). All radiographic measurements were performed by one of the authors (T.D.R.).

Activities of daily living and general postoperative quality of life were assessed with the Disabilities of the Arm, Shoulder and Hand (DASH) questionnaire at each visit, with a score of 0 representing no functional disability and a score of 100 representing complete disability[20]. In addition, patients were given a short questionnaire at the time of the twelve-week visit to determine their time away from work and to assess their satisfaction with the procedure and return to the pre-injury activity level. Patients were asked to rate their satisfaction with overall wrist function, wrist range of motion, digital range of motion, speed of recovery, and level of pain on a 5-point scale (very satisfied, satisfied, indifferent, dissatisfied, very dissatisfied) (see Appendix).

The number of major and minor complications following the surgical treatment of these injuries was tabulated. Major complications included loss of reduction, malunion, and nonunion as well as deep infection, neuropathy, and tendon rupture. Minor complications included transient extensor tendon irritation, superficial infections, and finger stiffness. Patients requiring additional interventions were identified, and the treatments were recorded.

Statistical Analysis

To determine statistical power, the primary outcome variable was the DASH functional outcome score. The present study was designed to determine a 10-point mean difference in the DASH score between the two groups, with a standard deviation of 10 points (for an effect size of 1.0)[20]. A power analysis indicated that a sample size of twenty-three patients randomized to each of the two groups would provide 90% statistical power to detect this effect size between the groups ($\alpha = 0.05$, $\beta = 0.10$) with use of an unpaired Student t test. The results for the two groups were compared with use of the Pearson chi-square test for categorical variables and the Student t test for continuous variables. Changes in DASH scores over time were assessed with a two-way repeated-measures analysis-of-variance F test. The level of significance was set at $p < 0.05$.

Source of Funding

No external funding sources were utilized for this study.

Results

Clinical Outcomes

The mean values for range of motion and grip and pinch strength for both groups are summarized in Table III. Patients in the open reduction and internal fixation group had greater range of motion and strength in all parameters as compared with patients in the closed reduction and percutaneous pin fixation group in the early postoperative period. The mean flexion-extension arc was significantly greater for the open reduction and internal fixation group over time ($p < 0.01$) (Fig. 2). Differences between groups were very pronounced at six weeks but decreased over time ($p < 0.01$). No difference in digital motion was detected between groups at six, nine, or twelve weeks or at one year postoperatively.

At six weeks postoperatively, the average DASH score was 27 in the open reduction and internal fixation group and 53 in the closed reduction and percutaneous pin fixation group ($p < 0.01$). At nine and twelve weeks, the difference was less pronounced but remained significant (17 compared with 39 [$p < 0.01$] and 11 compared with 26 [$p = 0.01$], respectively). By one year, the average DASH scores were similar in the two groups (4 compared with 9; $p = 0.18$). The average DASH scores were significantly lower in the open reduction and in-

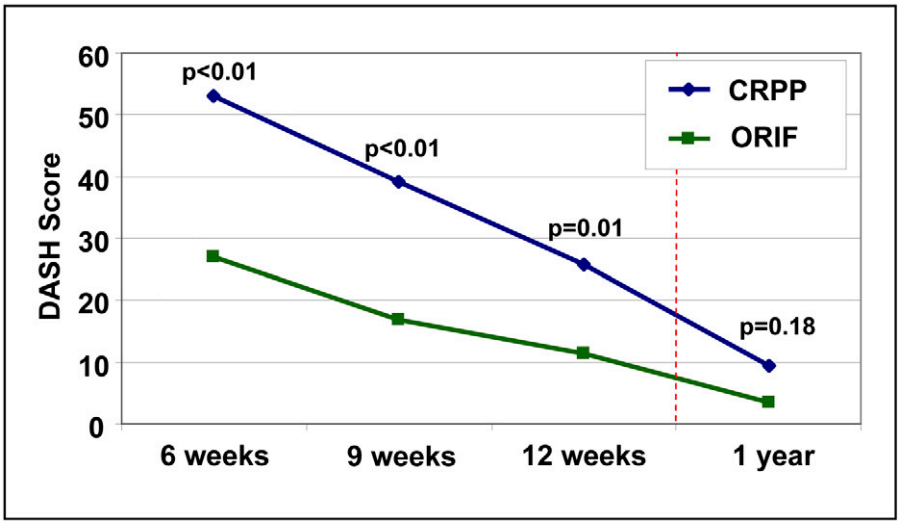

Fig. 3

Line graph illustrating the mean DASH scores for both groups. CRPP = closed reduction and percutaneous pin fixation, and ORIF = open reduction and internal fixation.

ternal fixation group over time ($p < 0.01$) (Fig. 3), and the difference in DASH scores between both groups decreased over time ($p = 0.02$).

Radiographic Outcomes

Adequate reductions were obtained in all cases at the time of surgery, and all fractures were united at six weeks after surgery. There were no cases of loss of reduction or malunion. In the immediate postoperative period, the mean values for radial height (11 compared with 11 mm; $p = 0.54$), radial inclination (22° compared with 21°; $p = 0.52$), and volar tilt (2° compared with 5°; $p = 0.09$) were similar in both groups. At the time of the latest follow-up, these measurements were essentially unchanged (Table IV). At the time of the one-year follow-up, there was no evidence of posttraumatic degenerative changes in any of the wrists.

Return to Work/Activities

Among patients who had been employed at the time of the injury, eighteen of eighteen in the open reduction and internal fixation group and fifteen of sixteen in the closed reduction and percutaneous pin fixation group returned to their preinjury work level ($p = 0.28$). The mean time to return to work (and standard deviation) was 17 ± 21 days in the open re-

TABLE IV Radiographic Outcomes

Radiographic Outcomes	Open Reduction and Internal Fixation*	Closed Reduction and Percutaneous Pin Fixation*	P Value
Radial height *(mm)*			
Immediate postoperative	11 ± 2	11 ± 2	0.54
Latest follow-up	11 ± 2	11 ± 2	0.85
Change	0.6 ± 2	0.3 ± 2	0.55
Radial inclination *(deg)*			
Immediate postoperative	22 ± 3	21 ± 3	0.52
Latest follow-up	21.0 ± 3	21 ± 4	0.99
Change	1 ± 3	0.1 ± 3	0.48
Volar tilt *(deg)*			
Immediate postoperative	2 ± 4	5 ± 5	0.09
Latest follow-up	3 ± 4	5 ± 5	0.07
Change	0.2 ± 3	0.2 ± 3	0.98

*The values are given as the mean and the standard deviation.

duction and internal fixation group, compared with 26 ± 27 days in the closed reduction and percutaneous pin fixation group (p = 0.35). Among patients who participated in recreational activities, seventeen of nineteen in the open reduction and internal fixation group and twelve of fourteen in the closed reduction and percutaneous pin fixation group returned to their preinjury activity level (p = 0.74).

At twelve weeks, more patients in the open reduction and internal fixation group were very satisfied with their overall wrist function (sixteen compared with seven; p = 0.02) and range of motion of the wrist (fourteen compared with five; p = 0.01). At twelve weeks, no difference was detected with regard to patient satisfaction in terms of digital motion (p = 0.1), pain (p = 0.24), or the perceived speed of recovery (p = 0.24).

Complications

Major complications in the open reduction and internal fixation group included one refracture resulting from a second fall (down a flight of stairs). Minor complications included one case of De Quervain tenosynovitis that was treated with a cortisone injection and splinting. There were no instances of tendon irritation or hardware removal. In the closed reduction and percutaneous pin fixation group, there were six complications (including one major complication and five minor complications). One patient had distal radioulnar joint instability, which was undetected at the time of the index procedure, and underwent closed reduction and pin fixation at five weeks postoperatively. In addition, one patient had extensor carpi ulnaris tendinitis, which resolved with a cortisone injection, and one patient had adhesive capsulitis of the shoulder, which was treated successfully with physical therapy. Three patients had pin-track infections, all of which responded to oral antibiotics. None of those patients required premature pin removal. There were no cases of neuropathy, deep infection, loss of reduction, or nonunion in either group, and no patients had digital stiffness.

No differences in major complications were detected (with one major complication occurring in each group). The rate of minor complications was greater in the closed reduction and percutaneous pin fixation group than in the open reduction and internal fixation group (five compared with one; p = 0.05), and the overall rate of complications was greater in the closed reduction and percutaneous pin fixation group than in the open reduction and internal fixation group (six compared with two; p = 0.07).

Discussion

Over the last decade, there has been a shift in the surgical approach for the treatment of distal radial fractures in favor of open reduction and internal fixation. In a review of cases submitted for the Part II oral examination of the American Board of Orthopaedic Surgery, Koval et al. recently documented the increasing popularity of open reduction and internal fixation, especially since the introduction of volar locking plates in 2001[21].

Although there is a large body of work concerning the treatment of distal radial fractures, there have been few randomized trials to guide our treatment of these injuries and the literature remains inconclusive[22-26]. In particular, there have been few series in which locked volar plate fixation has been compared with percutaneous fixation. Most of the existing trials have compared external fixation with either dorsal or volar plate fixation and have included fractures spanning the spectrum of severity, making it difficult for the reader to draw definitive conclusions. Kreder et al. performed a trial in which external fixation was compared with dorsal and/or volar plate fixation and found no differences between the groups at six months with regard to range of motion or SF-36 scores[27]. In a randomized intervention in which dorsal plate fixation was compared with external fixation for the treatment of intra-articular fractures, Grewal et al. reported no differences between the groups in terms of the DASH scores but reported a higher complication rate among patients managed with open reduction and internal fixation[17]. Their higher complication rate (including several cases of extensor tendon irritation and hardware removal) may have been largely attributable to the use of the dorsal Pi plate (Synthes) rather than other, low-profile devices[28]. Leung et al. reported better outcome scores and radiographic outcomes at two years postoperatively among patients who had been managed with open reduction and internal fixation (including dorsal, volar, and combined plate fixation) than among those who had been managed with external fixation for the treatment of intra-articular fractures[18]. In the only trial in which open reduction and internal fixation with exclusive use of volar locking plates was compared with external fixation, Egol et al. demonstrated better outcomes in the open reduction and internal fixation group at three months but similar outcomes at six and twelve months after treatment[19].

The current study examined the differences between treatment with closed reduction and percutaneous pin fixation and treatment with open reduction and internal fixation with use of a volar plate. In an effort to avoid crossover between groups and to limit fracture heterogeneity, only unstable extra-articular and simple intra-articular dorsally displaced fractures were included. On the basis of our hypothesis that open reduction and internal fixation leads to a faster return to function and previous evidence demonstrating similar long-term results for external and internal fixation[22-26], we chose to focus on the first three months after treatment. Also, previous studies comparing early and delayed mobilization following the fixation of distal radial fractures have not detected a significant difference in patient outcomes at three months or more after surgery[29,30]. Those studies suggested that the period of immobilization after treatment may not be the sole determinant of functional disability and that comparing groups as early as six weeks after surgery could provide meaningful information. We found that, in the early postoperative period, patients who had been managed with open reduction and internal fixation had better range of motion and strength and lower DASH scores than did those who had been managed with closed reduction and percutaneous pin fixation. This difference

was particularly pronounced in the first six and nine weeks after the injury (as indicated by differences in the DASH score of 26 and 22 points, respectively) and then decreased over time. Furthermore, patients managed with open reduction and internal fixation also had better satisfaction scores than those managed with closed reduction and percutaneous pin fixation.

In the present study, the complication rate was 8.7% in the open reduction and internal fixation group as compared with 27% in the closed reduction and percutaneous pin fixation group; however, most of the complications were minor and resolved without operative intervention. Early series of distal radial fractures that were treated with volar plating demonstrated complications in as many as 25% of cases[14,31]. The lower complication rate in the present study parallels that documented in the more recent literature and reflects stringent patient-selection criteria as well as increasing familiarity with the technique. In addition, the omission of complicated fracture patterns included in other studies likely contributed to our lower rate of complications.

The present study confirms the hypothesis that volar plate fixation results in less functional disability in the first few months after treatment than does percutaneous pin fixation. At one year after the injury, we did not identify a difference between the treatment groups with regard to functional or radiographic outcomes. The reasons for better early outcomes in the open reduction and internal fixation group may include less restrictive immobilization (a removable splint as compared with a cast), the use of early range-of-motion protocols, and the ability to rapidly incorporate the injured extremity into the activities of daily living. Given that only thirty-four patients were employed at the time of the injury, we were not able to detect a difference between the two groups with regard to the average time to return to work. On the basis of our data demonstrating less functional disability among patients managed with open reduction and internal fixation, however, we can infer that this treatment modality should be considered for patients desiring a more rapid return to function after an injury.

The present study had several limitations. Complex intra-articular fractures were excluded from the analysis and, as such, the results cannot be generalized to patients with these injuries (including some type-C2 and C3 injuries). Although we used the DASH as a primary outcome measure, there are other outcome measures that could have been employed. Additional information may have been derived from the use of a wrist-specific scoring system. Finally, there was some heterogeneity in the choice of volar plate, which was left to the individual preference of the operating surgeon. Despite these shortcomings, our results demonstrated that open reduction and internal fixation with a volar plate and closed reduction with percutaneous pin fixation both resulted in excellent clinical and radiographic outcomes when used for the treatment of dorsally displaced distal radial fractures. However, patients managed with a volar plate had better range of motion and grip strength and had lower DASH scores in the early postoperative period. This may be responsible for the recent enthusiasm for volar plating of distal radial fractures.

Appendix

eA The patient satisfaction and return-to-work questionnaire is available with the electronic versions of this article, on our web site at jbjs.org (go to the article citation and click on "Supplementary Material") and on our quarterly CD/DVD (call our subscription department, at 781-449-9780, to order the CD or DVD). ■

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