

Distal radial osteotomy for malunion using non-bridging external fixation

Good results in 23 patients

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Background and purpose Symptomatic malunion of the distal radius is a common problem and is treated by distal radial osteotomy. Plating is commonly used but has a high rate of plate removal. This study is a report of the functional and radiographic outcome of a prospective series of distal radial osteotomies using non-bridging external fixation.

Methods 23 patients with a median age of 60 (18–84) years underwent distal radial osteotomy using non-bridging external fixation and bone grafting for dorsal malunion of a fracture of the distal radius. There were no cases of intraarticular malunion. Radiographic, functional, and patient-assessed outcomes were assessed preoperatively and until 6 months after surgery.

Results The mean preoperative dorsal angle of 20 (5–40) degrees was corrected to over 5 (0–15) degrees of volar tilt ($p < 0.001$) and the mean preoperative positive ulnar variance of 3.9 (0–8) mm was corrected to 2.5 (0–8) mm ($p = 0.005$). Carpal alignment was restored in 22 of the 23 patients. 5 patients required simultaneous ulnar surgery, 1 required ulnar shortening, and 4 required modified Bower's procedures. By 6 months postoperatively, all measures of function except extension and key grip strength showed statistically significant improvements in their means. The SF36 showed statistical improvements in two domains, role physical and bodily pain. There were 2 patients with extensor pollicis longus ruptures and 13 with minor pin-track infections.

Interpretation Distal radial osteotomy for dorsal malunion of the distal radius using non-bridging external fixation is a successful technique for correction of

deformity and restoration of function, with the advantages of being less invasive and not requiring further surgery for removal of metalwork. ■

Distal radial fractures have a high rate of dorsal malunion (McQueen 2006). When the malunion is persistently symptomatic then distal radial osteotomy is indicated in fit patients, irrespective of age.

There have been a number of previous studies of patients undergoing radial osteotomy, mostly reporting the use of plates to stabilize the osteotomy (Fernandez 1988, Brown and Bell 1994, Hove and Mølster 1994, Jupiter and Ring 1996, Prommersberger et al. 2002, von Campe et al. 2006). Where reported, plate removal rates have been high, ranging from 25% to 54%—either because of established or expected tendon rupture or irritation (Hove and Mølster 1994, Jupiter and Ring 1996, Prommersberger et al. 2002, von Campe et al. 2006). Plating of a dorsal opening-wedge osteotomy requires an extensive dorsal approach and is a complex procedure. This accounts for the relatively high rate of residual deformity after healing, which ranges from 38% to 60% even in expert hands (Brown and Bell 1994, Hove and Mølster 1994, Prommersberger et al. 2002, von Campe et al. 2006).

Reported success with the use of non-bridging external fixation in the management of unstable fractures of the distal radius (McQueen 1998,

McQueen et al. 1999) has led to the use of non-bridging external fixation for radial osteotomy in an attempt to reduce the secondary surgery rate after plating, and to improve the radiographic and functional results of the procedure.

We report the functional and radiographic outcome of a prospective series of distal radial osteotomies for dorsal malunion using non-bridging external fixation.

Patients and methods

Between July 1997 and January 1999, 23 patients (median age 60 (18–84) years, 16 female) underwent distal radial osteotomy for symptomatic dorsal malunion of the distal radius. Malunion was defined as more than 10 degrees of dorsal angulation (Van der Linden and Ericson 1981), more than 2 mm of radial shortening (Melone 1984), or carpal malalignment (McQueen et al. 1996). 16 patients had sustained their original fracture in a fall from standing height, 2 in a fall from a height, 2 from sport injuries, and 3 from a direct blow. 12 patients had had extraarticular fractures (AO A3.2) and eleven had intraarticular fractures (AO C2.1) (Muller et al. 1990). All had metaphyseal malunion in dorsal displacement; none had intraarticular malunion. The indications for osteotomy were one or more of the following: weakness of grip (5), distal radioulnar joint pain (16), carpal pain (9), reduced forearm rotation (13), carpal tunnel syndrome (3).

Surgery was performed by the senior author (MMcQ) at an average of 11(8–34) months after fracture. Under tourniquet control, a 2.5-cm transverse skin incision was made over the site of the original fracture. The extensor retinaculum was divided longitudinally and the radius exposed between the third and fourth compartments. The site of the osteotomy, usually at the area of deformity, was identified. 2 Hoffman II compact fixator pins were then inserted by hand through 2 separate longitudinal incisions, protecting the extensor tendons. The pins were placed using fluoroscopy midway between the planned site of the osteotomy and the radiocarpal joint, parallel to each other and to the radiocarpal joint on the lateral view. The pins must engage the volar cortex. An osteotomy cut was then made with a small saw, proximal and



Radial osteotomy. The volar tilt has been regained and bone graft can be seen filling the metaphyseal defect. Note that the distal pins are parallel to the joint surface and engage the volar cortex.

parallel to the pins and as far as—but not dividing—the volar cortex. An osteotome was inserted into the osteotomy cut and the volar cortex was cracked by creating an open wedge dorsally. 2 pins were then placed in the radial diaphysis proximal to the osteotomy. After assembly of the fixator, the distal pins were used as a “joystick” to position the distal fragment. The wedge-shaped defect in the distal radius was filled with cancellous bone harvested from the iliac crest (Figure). The osteotomy wound was closed but the pin track incisions were left open. Extensor pollicis longus was left in its compartment, as the osteotomy incision does not expose it. At this stage, the range of rotation was assessed. If rotation had not been restored by the osteotomy then a further procedure was performed under the same anesthetic. 4 patients whose radial length had been restored by the osteotomy underwent a modified Bower’s procedure (Gaebler and McQueen 2003) and 1 patient who had a residual ulnar plus deformity underwent a combined ulnar shortening and modified Bower’s procedure.

Postoperatively, the hand was elevated and wrist and hand movements were not restricted. Physiotherapy was prescribed as clinically indicated. The fixator was removed when radiographs showed bone filling in the osteotomy defect. This was at an average of 40 (34–43) days postoperatively.

Patients were reviewed clinically, functionally, and radiographically at regular intervals. Clinical review was carried out preoperatively, immediately postoperatively, and at 6 weeks, 12 weeks, and 26 weeks postoperatively. No patients were lost to follow-up, although one patient underwent radiographic examination and completed an SF36 form at 26 weeks but refused functional testing. Major complications were defined as those that required further surgery or compromised the final functional outcome. Minor pin-track infection was defined as inflammation or discharge from pin sites that was successfully treated with antibiotics and pin-track dressings. Major pin-track infections were those that required further surgery or early removal of the fixator for resolution to occur.

Radiographic review was performed preoperatively, immediately postoperatively, and at 6 and 26 weeks postoperatively, including radiographs of the opposite (normal) wrist at 6-week review only. Standard anteroposterior and lateral films were obtained for measurements of dorsal angulation (Van der Linden and Ericson 1981) and ulnar variance (Melone 1984). Ulnar variance was calculated using the normal side as a reference. Carpal alignment was assessed as previously reported (McQueen et al. 1996).

Functional review was performed by AW preoperatively, when the fixator was removed, and at 12 and 26 weeks postoperatively. Pain at rest was evaluated using a visual analog scale (VAS) ranging from 0 to 10 cm. The range of movement was measured using a standard full-circle goniometer. Flexion, extension, pronation, supination, and radial and ulnar deviation were each measured in triplicate and the mean of the three measurements was recorded to minimize intraobserver bias. Each measurement was expressed as a percentage of the opposite, unaffected side.

The mass grip strength was measured using a JAMAR hand dynamometer (Therapeutic Equipment Corp., Clyton, NJ). In accordance with the guidelines for the use of the JAMAR dynamometer issued by the American Society for Surgery of the Hand (ASSH 1983), the second grip handle was used for all patients. The means of 3 successive trials were used on both injured and uninjured hands and recorded as percentage of the unaffected side, as recommended by the American

Society of Hand Therapists (ASHT 1981). The same subjects were tested at similar times of the day at each assessment to minimize the affect of diurnal variation. Grip strengths were adjusted by 10% for the non-dominant hand (Bechtol 1954). Chuck, key, and pinch grip strengths were also measured.

The ability to perform 11 activities of daily living such as turning a key, opening a jar, and threading a needle were assessed using an adaptation of a validated functional assessment scoring system (Sheehan et al. 1983). Results were scored according to the degree of difficulty in performing these activities (with zero representing impossible, 1 representing some difficulty, and 2 representing no difficulty), giving a maximum possible total of 22. Raw scores were converted into percentages for analysis. Patient-assessed outcome was measured using the SF36 (Ware et al. 1993) preoperatively and at the 6-month review.

Statistics

Differences between the means (and 95% confidence intervals) for the preoperative and 12-week scores and the preoperative and 26-week scores were calculated for the functional and radiographic outcomes. The Wilcoxon signed rank test was used to examine these differences over time. Chi-squared tests were used to compare the proportion of patients with carpal malalignment preoperatively and postoperatively. Statistical significance was assumed for p-values of less than 0.05. The association between age and functional outcome and age and the three grip types was measured using Spearman's rank correlation test.

Results

Radiographic results (Table 1)

The mean preoperative dorsal angle was 20 degrees, which improved to a mean volar tilt of 6.4 degrees at 6 months. Radial length also improved. Only 1 patient required simultaneous ulnar shortening. 21 patients regained normal alignment of the carpus ($p < 0.001$).

Function (Tables 2 and 3)

All measures of function improved statistically

Table 1. Radiographic results

	Preoperatively mean (SD)	At 26 weeks mean (SD)	Difference in means (95% CI)	P-value
Dorsal angulation (°)	20 (10)	-6.4 (6.5)	26 (22–31)	< 0.001
Ulnar variance (mm) ^a	3.9 (2.2)	2.5 (2.4)	1.4 (0.5–2.3)	0.005

^a 4 patients underwent simultaneous modified Bower's procedures and one underwent simultaneous ulnar shortening.

Table 2. Mean outcome scores (with SD) preoperatively, at 12 weeks (n = 23), and at 26 weeks (n = 22) expressed as percentage of the unaffected side

Outcome measure	Preoperatively	At 12 weeks	Difference in means (95% CI)	P-value	At 26 weeks	Difference in means (95% CI)	P-value
Pain	3.8 (2.4)	2.5 (2.1)	-1.3 (-2.1– -0.3)	0.01	2.3 (2.4)	-1.6 (-2.7–0.5)	0.01
Pronation	77 (29)	87 (22)	9.9 (0.5–20.2)	0.03	89 (17)	11 (0.4–20)	0.04
Supination	68 (28)	81 (22)	13 (2.3–24)	0.01	87 (19)	19 (7.2–30)	0.001
Flexion	47 (19)	75 (22)	28 (20–36)	<0.001	82 (19)	35 (27–43)	< 0.001
Extension	79 (25)	77 (22)	1.7 (-15–12)	0.6	84 (27)	6.0 (-12–24)	1
Radial deviation	74 (32)	89 (27)	15 (1.0–30)	0.03	100 (29)	25 (5.1–45)	0.02
Ulnar deviation	61 (24)	72 (22)	11 (1.2–21)	0.03	78 (20)	18 (6.1–31)	0.01
Functional score	74 (16)	87 (13)	13 (5.3–21)	0.004	93 (8)	20 (13–26)	< 0.001
JAMAR	30 (21)	42 (21)	13 (1.8–23)	0.04	56 (38)	27 (6.6–48)	0.01
Chuck	65 (21)	80 (31)	15 (0.12–31)	0.1	87 (35)	25 (6.7–43)	0.005
Key	71 (22)	74 (27)	2.3 (-12–16)	0.6	83 (33)	13 (-1.8–28)	0.08
Pinch	68 (23)	85 (32)	18 (4.6–31)	0.02	80 (32)	17 (-0.5–35)	0.08

Table 3. Mean SF 36 scores (with SD) preoperatively and after 6 months (n = 22)

Health domain	Preoperatively	Postoperatively	Mean difference (95% CI)	P-value
Physical function	65 (27)	71 (26)	5.5 (-5.5–17)	0.06
Role physical	16 (33)	55 (45)	39 (14–64)	0.02
Bodily pain	47 (22)	61 (28)	13 (2.4–24)	0.03

significantly by 12 weeks postoperatively, except extension and chuck and key grip. Improvement in all of these indices progressed during the 12 to 26-week period so that by 26 weeks after osteotomy, only extension and key pinch grip strength had not improved significantly compared to the preoperative level.

The mean level of pain had improved significantly by 12 weeks and this was maintained at 26 weeks. There was no deterioration in the level of pain in any particular patient.

The functional score improved from a mean of 74% of normal preoperatively to a mean of 93% of normal by 26 weeks. None of the patients failed to improve their ability to perform the normal activities of daily living by 6 months after osteotomy. There was no correlation between age and functional outcome or grip strength.

Of the 8 domains tested with the SF36 scores, 2 were statistically significantly improved at 6 months postoperatively: role physical and bodily pain.

Complications

13 of the 23 patients experienced complications of the surgery or fixation. Only 2 patients experienced major complications (i.e. those that might compromise final function). These were 2 patients with extensor pollicis longus ruptures. Both patients refused extensor transfer because of minor limitation of function. There were no cases of postoperative carpal tunnel syndrome, reflex sympathetic dystrophy, nonunion, or bone graft donor site problems. All 13 pin-track infections were minor.

Discussion

In this series of 23 cases of distal radial osteotomy for dorsal malunion of the distal radius performed using non-bridging external fixation, consistently good results were achieved—both radiographically and functionally. As in the use of non-bridging external fixation for acute fractures (McQueen 1998), radial osteotomy using this technique will regain and maintain the normal volar tilt and carpal alignment, which has been shown to have a positive influence on functional outcome.

Radial length is also improved by this technique, although ulnar shortening is still required in more severe cases. This is a limitation of this technique, but it is also a limitation of other techniques of distal radial osteotomy where it is acknowledged that 7 mm is generally the maximum length correction achievable by radial realignment alone (Gaebler and McQueen 2003). Limitation of improvement in radial length is a result of the technique of cracking rather than dividing the volar cortex, which confers added stability to the construct of the external fixation. If the volar cortex is divided, there is a risk of over-correction of the dorsal tilt and resultant volar malunion. However, rotation of the forearm was restored by the osteotomy in all but 4 of the patients, who required ulnar procedures added to their osteotomy. Only one of these patients had significant length imbalance requiring an ulnar shortening. This compares favorably with the experience of other authors where the requirement for ulnar procedures ranges from 19% to 60% (Brown and Bell 1994, Hove and Mølster 1994, von Campe et al. 2006).

The technique is simple and minimally invasive, employing only a 2.5-cm transverse incision plus

incisions for pin placement. The surgical incision is in a skin crease and therefore heals with less scarring than the longer longitudinal scar that is required to plate a radial osteotomy. The amount of stripping of soft tissues from the radius is limited to the amount required to allow access for the saw. This appears to cause less swelling postoperatively than plating techniques with a larger exposure, although this was not tested formally in this study. Removal of the external fixator is undertaken in an outpatient setting, thus minimizing admission for removal of implants—which is commonly required after plating (Hove and Mølster 1994, Jupiter and Ring 1996, Prommersberger et al. 2002).

Function, range of movement, and strength were all regained rapidly. By 26 weeks, the ability to perform the activities of daily living had improved to nearly normal and there were major improvements in the patients' perceptions of their condition, as evidenced by the SF36 scores for role physical and bodily pain. Pain as assessed by VAS (0–10) had improved by an average of 1.5 by 26 weeks after surgery. Minimum clinically significant differences in the VAS score for pain are considered to range from 0.9 cm to 1.5 cm (Kelly 2001). All ranges of movement are markedly improved except extension. This is predictable, as the surgery restores volar tilt, thus moving the flexion/extension arc towards flexion. Most of our patients regained supination without further surgery on the distal radio-ulnar joint, but such improvement in supination depends on examination of the range of movement after completion of the procedure and the use of further ulnar procedures if indicated (Gaebler and McQueen 2003). Mean mass grip strengths almost doubled in 26 weeks, although the mean grip strength at 26 weeks remained relatively low—at half of normal. If the review period were to be extended, however, it might be anticipated that this would improve further—particularly in view of the fairly prolonged period of time that most of these patients' grip strengths had been limited by the malunion preoperatively.

Major complication rates were low, with only 2 extensor pollicis longus ruptures in this series. This still represents a relatively low risk of extensor pollicis longus rupture compared to dorsal plating, which is known to irritate the extensor tendons and generally has a high rate of plate removal

(Hove and Mölster 1994, Jupiter and Ring 1996). The advent of locking plates for the distal radius has allowed stabilization of acute fractures from the volar surface, but tendon irritation or rupture rates remain disappointing (Drobetz and Kutcha-Lissberg 2003, Rozental and Blazar 2006). To date, there are no robust data available regarding the use of volar locked plates in the treatment of dorsal malunion, although the results of distal radial malunion have been reported using non-locked volar plates (Prommersberger et al. 2002). This technique allows restoration of the anatomy but of 29 patients treated for dorsal malunion in this series, 20 required plate removal. The main disadvantage of the non-bridging external fixation is the occurrence of minor pin-track infection. These infections require increased dressings and oral antibiotics, and in this study none compromised the final function or required added surgery.

In conclusion, distal radial osteotomy using non-bridging external fixation is a reliable technique for correction of the deformity and restoration of function. The technique has the advantage of being minimally invasive and there is no need for further surgery to remove metalwork.

Contributions of authors

AW collected data, undertook functional testing, and participated in interpretation and analysis of data and drafting of the manuscript. MMcQ was responsible for conception and design of the study and for critical revision of the manuscript.

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