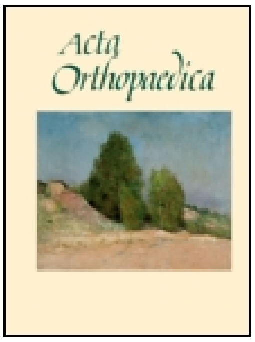

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Bridging and non-bridging external fixation in the treatment of unstable fractures of the distal radius

A retrospective study of 588 patients

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Background and purpose **Bridging external fixation is used more frequently than non-bridging fixation in the management of unstable distal radius fractures, despite evidence from randomized controlled trials of better outcome with the latter technique. This study was designed to investigate the generalizability of the technique of non-bridging external fixation, and to define the indications for the use of each technique and their complications.**

Methods **641 patients with unstable displaced fractures of the distal radius were treated with bridging or non-bridging external fixation. Non-bridging external fixation was used where there was space for pins in the distal fragment. 52 patients were lost to follow-up, leaving 588 patients available for study. Complete data from radiographic measurements after fracture healing were available for 546 patients. 59% of fractures were treated with the non-bridging technique.**

Results **Fractures treated with bridging external fixation had a 6 times increased risk of dorsal malunion ($p < 0.001$) and a 2.5 times increased risk of radial shortening ($p < 0.001$) after adjusting for confounding factors (95% CI for odds ratio: 3–13 and 1.5–4, respectively) compared to non-bridging techniques. Minor pin tract infections were more common in the non-bridging group.**

Interpretation **Non-bridging external fixation of the distal radius is a generalizable technique, and reduces the risk of dorsal malunion compared with bridging external fixation. Major complication rates are low and the technique is applicable to most unstable fractures of the distal radius. We recommend that non-bridging external fixation be used where there is space for the pins in the distal fragment.**

■

Fractures of the distal radius can be stabilized with external fixation, either bridging or non-bridging. Although non-bridging external fixation has been shown in a randomized controlled trial to have better radiographic and functional outcomes than bridging external fixation (McQueen 1998), the latter study was performed by an orthopedic trauma surgeon with a special interest in fractures of the distal radius. For a technique to be useful, however, it must be generalizable—i.e. it must give similar results when used by the orthopedic community in general to those obtained in specialist hands in a randomized controlled trial. The generalizability of non-bridging external fixation for distal radius fractures and its pitfalls, complications, and indications for use have not been documented previously. Barriers to the use of the technique include (1) its applicability in limited numbers of fractures, (2) technical difficulty (only allowing success in experienced hands), (3) possible pin pull-out from osteoporotic bone, and (4) the danger of damage to extensor tendons (Bednar and Al-Harran 2004, McQueen 2005). This study was designed to allow us to define the indications for the use of non-bridging and bridging external fixation for unstable fractures of the distal radius, to describe their complications, and to compare the radiographic outcome when used by inexperienced and experienced surgeons. The main hypothesis of the study was that the technique of non-bridging external fixation is generalizable to orthopedic surgeons who do not specialize in wrist trauma, and that if external fixation is used, the majority of distal radius fractures would be suitable for treatment with non-bridging techniques.

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Patients and methods

Over a 6-year period (1995–2000), 641 patients with fractures of the distal radius were treated according to established unit protocols with external fixation at our institution, Royal Infirmary of Edinburgh. During this period, 6,260 patients with distal radial fractures were treated in our unit. Indications for external fixation were either primary or secondary metaphyseal instability, displaced intra-articular fractures or open fractures, in patients living independently and deemed fit for anesthetic regardless of their age. Primary instability was defined as failure of fracture reduction or a combination of metaphyseal comminution, substantial radial shortening, and advanced age (Mackenney et al. 2006). Secondary instability was defined as the failure to hold a reduced position of the fracture within a forearm cast. Patients with redisplacement to dorsal angulation of more than 10 degrees, radial shortening of more than 3 mm, or carpal malalignment were considered unstable (McQueen 1998, Mackenney et al. 2006).

The fractures were treated either by bridging or non-bridging external fixation. A non-bridging fixator was placed if, in the opinion of the operating surgeon, there was sufficient space in the distal fragment to insert the pins. Where there was insufficient space for pins in the distal fragment, a bridging external fixator was used with or without augmentation (at the surgeon's discretion). Articular displacement was reduced by closed means if possible, but open reduction was used where closed reduction failed.

Demographic data were collected prospectively for all patients. This included their sex, age at injury, mode of injury, indication for surgery, type of external fixator, and whether the fracture was an open or closed injury. All data were complete except for 13 patients in whom the mode of injury was unknown. Further information was collected retrospectively from review of case notes and radiographs, and this included AO classification (Muller et al. 1990), Gustilo's classification for open fractures (Gustilo and Anderson 1976), seniority of the operating surgeon, duration of fixation, complications, and radiographic measurements. 52 patients were lost to follow-up before the minimum 3-month period. 28 of these lived outside the area, and 4 others died. Radiographs for 43 patients were missing at final review. Thus, data on 588 patients were analyzed for the purposes of defining indications for the techniques and complications, and data from 546 patients were analyzed for radiographic outcome. 229 patients were treated for primary instability or intra-articular displacement. The indication for surgery in the remaining 359 patients was secondary instability.

Patients were reviewed for a minimum of 3 months until fracture healing by radiography, or longer. The average review period was 175 (84–792) days. Radiographic measurements included dorsal angulation, shortening, and carpal malalignment. The radiographs were measured by a trained research nurse who was not involved in the care of the patients at initial presentation. Dorsal angulation was measured using the technique of Van der Linden and Ericson (1981) and expressed as the number of degrees from the neutral position, expressing volar tilt as a negative value. Radial shortening was measured as the vertical distance between the ulnar border of the distal radius and the most distal point of the head of the ulna (Melone 1984). Secondary compensatory carpal malalignment was defined on a lateral view as the dorsal or volar displacement of the longitudinal axis of the capitate in relation to the long axis of the radius (McQueen et al. 1996).

Malunion was defined as either dorsal angle greater than 0 with carpal malalignment, volar angle less than –15 degrees with carpal malalignment, radial shortening of more than 3 mm, or a combination of these measurements (Ruch 2006).

Minor pin-track infection was defined as inflammation around or discharge from one or more pin sites requiring treatment with antibiotics, or an increased frequency of dressing changes. Major pin-track infection required early removal of the fixator or one or more added surgical procedures.

The operative technique was standardized. The Hoffman II compact fixator (Stryker, Kalamazoo, MI) was used in all cases with 2-mm fixator pins. For the non-bridging fixator, the distal pins were inserted by an open technique using two 1-cm longitudinal incisions in the extensor retinaculum on either side of Lister's tubercle, taking care to protect the tendon of extensor pollicis longus. 2 fixator pins were then placed from a dorsal to a volar direction, parallel to the radiocarpal joint in the lateral view and engaging the volar cortex. In 6 cases with intra-articular displacement, the joint surface was first reduced percutaneously and held with K-wires. 2 pins were inserted into the radial shaft again using an open placement technique. Gentle pressure on the distal pins was used to reduce the fracture with a joystick technique.

The bridging external fixators were placed using 2 parallel pins in the base of the second metacarpal, and 2 into the shaft of the radius by an open technique. Reduction was performed with longitudinal traction or Agee's technique (Agee 1993), aided by fluoroscopy. In 16 cases, the fixator was augmented with unthreaded percutaneous wires to support the metaphyseal alignment at the discretion of the treating surgeon. In 15 cases there was intra-articular displacement, which required percutaneous reduction and fixation with K-wires. Bone graft was used as augmentation in one of these cases. Open reduction was performed in 2 cases.

Table 1. Summary of demographic data

	Total (%)	Bridging (%)	Non-bridging (%)	P-value
Fractures	588 (100)	230 (39)	358 (61)	
AO classification				
AO A3.2	224 (38)	31 (13)	193 (54)	< 0.001
AO C2.1	167 (28)	62 (27)	105 (29)	
AO C3.2	112 (19)	100 (43)	12 (3)	
Other	85 (15)	37 (16)	48 (13)	
Open fracture	46 (8)	23 (10)	23 (6)	0.2
Gender				
Male	118 (20)	71 (31)	47 (13)	< 0.001
Female	470 (80)	159 (69)	311 (87)	
Operating surgeon				
Consultant	114 (19)	36 (16)	78 (22)	0.08
Trainee	474 (81)	194 (84)	280 (78)	
Resulting from fall	441 (75)	152 (66)	289 (81)	< 0.001
Average age (years)				
Overall	61	58	64	< 0.001
Male	47	42	53	0.005
Female	65	65	65	0.1
Duration of fixation (days)	40	41	39	0.07

Statistics

Statistical analysis was performed by an independent statistician. Associations between variables were tested by chi-squared test, t-tests, or Pearson correlation as appropriate, and multiple logistic regression was used to test the significance of prognostic factors in predicting outcomes after adjusting for one another. Adjustments were made for all demographic factors shown in Table 2, as well as for initial radial shortening and dorsal angle. A p-value of less than 0.05 was deemed to be significant.

Results

Patient and fracture data

The average age of the 588 patients (470 women) was 61 (16–96) years. 358 fractures (61%) were treated with a non-bridging external fixator and 230 with a bridging fixator. The average age of the men was 47 (16–85) years and that of the women was 65 (17–96) years. Bridging fixation tended to be used more in younger patients ($p < 0.001$) and in males ($p = 0.005$) (Table 1).

Three-quarters of the fractures were the result of a simple fall. This low-energy mode of injury was more common in the non-bridging group ($p < 0.001$) (Table 1). 44 fractures were open: 33 Gustilo type 1, 7 type 2, and 4 type 3a. Of all the fractures, 38% were OTA/AO class A3.2, 28% were class C2.1, and 19% were class C3.2. 58% were intra-articular. However, only 7% of these patients had significant intra-articular displacement (a gap or step of more than 2 mm). There were more A3.2 fractures in the non-bridging group, and correspondingly more C3.2 fractures in the bridging group ($p < 0.001$). Data on AO classification were missing for 43 patients. These were patients whose radiographs were missing, and they were excluded from the outcome analysis.

Table 2. Results of radiographic measurements of distal radius fractures at four stages of treatment. Values shown are mean for dorsal angle and shortening, and percentage for carpal alignment. The p-values for final outcomes are shown both unadjusted and adjusted for all the factors in Table 1, and also for initial levels of each of the three radiographic measurements. Numbers in parentheses are 95% confidence limits for mean difference or odds ratio for bridging as compared to non-bridging

	Bridging	Non-bridging	Unadjusted p-value	Adjusted p-value
Dorsal angle (°)				
Initial	23	25	0.05	
Preoperative	14	17	0.009	
Postoperative	–0.3	–5.5	< 0.001	
Final	1.5	–6.6	< 0.001	< 0.001 (5.5–9.9)
Shortening				
Initial	4.0	5.3	< 0.001	
Preoperative	3.5	2.8	0.020	
Postoperative	1.5	0.8	< 0.001	
Final	2.8	1.6	< 0.001	< 0.001 (0.3–1.3)
Carpal alignment (%)				
Initial	12	4.4	0.004	
Preoperative	20	11	0.06	
Postoperative	87	90	0.4	
Final	63	84	< 0.001	< 0.001 (0.18–0.55)

Table 3. Complications of distal radius fractures

Complications	Total	Bridging (%)	Non-bridging (%)	P-value
Overall	226	75 (33)	151 (42)	0.03
PTI (minor)	126	30 (13)	96 (27)	< 0.001
PTI (major)	12	4 (2)	8 (2)	0.9
Carpal tunnel syndrome	25	11 (5)	14 (4)	0.8
CRPS	37	16 (7)	21 (6)	0.7
EPL rupture	8	1 (0.4)	7 (2)	0.2
Failure of external fixation	11	2 (0.9)	9 (3)	0.3
Radial nerve injury	8	3 (1)	5 (1)	1.0
Ulnar neuropraxia	7	4 (2)	3 (0.8)	0.6
Metacarpal fracture	3	3 (1)	0 (0)	0.1
Delayed union	3	1 (0.4)	2 (0.6)	1.0
Athrodesis	2	2 (0.9)	0 (0)	0.3
Compartment syndrome	5	3 (1)	2 (0.6)	0.6
Dorsal malunion	66	50 (24)	16 (5)	< 0.001
Volar malunion	26	8 (4)	18 (5)	0.6
Shortening > 3 mm	219	112 (54)	107 (32)	< 0.001

PTI: pin-track infection;
CRPS: complex regional pain syndrome;
EPL: extensor pollicis longus.

The status of the operating surgeon was similar for both groups, with most cases operated by an orthopedic surgeon in training. Fixators were removed when the fracture was deemed to be healed radiographically. The average length of fixation for the whole group was 40 (12–75) days. The indication for early removal of the fixator was a major pin-track infection or failure of fixation and conversion to internal fixation. The average length of fixation was similar: 39 days for the non-bridging group and 41 days for the bridging group.

Radiographic outcome

Non-bridging external fixation succeeded in maintaining the volar tilt achieved at surgery, which was better than bridging external fixation ($p < 0.001$), but lost a mean of just under 1 mm of radial length during the period of review (Table 2). Carpal alignment was restored in 84% of cases. In contrast, bridging external fixation restored—but was less successful in maintaining—the reduced position, with only 63% of cases showing carpal alignment at final review. Thus, patients treated with bridging external fixation had more malunions than those treated with non-bridging fixation ($p < 0.001$) (Table 3). There were 8 volar and 50 dorsal malunions in the bridging group. In the non-bridging group, there were 18 volar and 16 dorsal malunions. The odds ratios for malunion after adjustment for confounding factors (Table 4) revealed a 6 times increased risk of developing dorsal malunion with the use of a bridging external fixator than with a non-bridging fixator. Radial shortening was 2.5 times more likely with bridging external fixation.

Table 4. Odds ratios (95% confidence limits) for outcomes in bridging as compared to non-bridging patients after adjustment for possible confounding factors

	Odds ratio	P-value
Carpal tunnel syndrome	0.8 (0.2–2.7)	0.7
CRPS	1.0 (0.4–2.5)	1
Minor PTI	0.3 (0.2–0.6)	< 0.001
Volar malunion	0.7 (0.2–2.5)	0.6
Dorsal malunion	6.2 (3–13)	< 0.001
Shortening > 3 mm	2.5 (1.5–4)	< 0.001

Of the 22 patients with intra-articular displacement, 7 had intra-articular malunion with a residual step or gap of more than 2 mm. Of these, 2 have required radiocarpal arthrodesis.

Complications

226 of the 588 patients (38%) experienced complications of the fracture or surgery. Only 3, carpal tunnel syndrome (CTS), complex regional pain syndrome (CRPS), and minor pin-track infection (PTI), were sufficiently common to justify detailed analysis (Table 3).

CTS was more prevalent in the under-50 age group ($p < 0.001$) and in A3.2 fractures ($p = 0.04$). There was no difference in numbers of CTS between the bridging and non-bridging groups. CRPS was more common in open fractures ($p = 0.008$), but again, no difference was seen between treatment groups.

Minor PTIs were more common when non-bridging fixation was used ($p < 0.001$). They were also more common in closed injuries ($p = 0.04$). There were small numbers of major pin-track infections in each group, none of which led to persistent deep infection after fixator removal.

Pin pullout occurred in 1 case in the non-bridging group and in 3 cases in the bridging group.

Discussion

We found that in a large series of unstable distal radius fractures, non-bridging external fixation reduced the risk of dorsal malunion by a factor of 6 compared to the use of bridging external fixation, and reduced the risk of radial shortening by a factor of 2.5. In arriving at this conclusion, all statistically significant possible confounding factors were taken into account—including the severity of the injury, the age and sex of the patient, and the experience of the surgeon.

Similar results have been reported previously in a randomized study (McQueen 1998), but with smaller numbers and with a single experienced surgeon. Our study was designed as the next step: to investigate the generalizability of these results in less experienced hands. The results in the present series were achieved by surgeons in training in the majority of cases, and the success of this technique in inexperienced hands demonstrates its ease of use. Provided the distal pins are placed parallel to the radiocarpal joint in the lateral view and engage the volar cortex, then reduction is simple using a "joystick" technique, which allows direct control of the position of the distal fragment. The reduction is also maintained in the long term with a mean volar tilt of 6–7 degrees and restoration of carpal alignment at final radiographic review. Reduction and maintenance of reduction is more difficult using bridging external fixation because there is indirect control of the distal fragment, which depends on ligamentotaxis; this may not be successful in restoring the volar tilt (Bartosh and Saldana 1990) or the radial length. The results for radial length are remarkably similar to those in the original randomized study (McQueen 1998), with loss of length in both after fixator removal but more so in the bridging group. In a randomized study comparing bridging and non-bridging external fixation of the distal radius, Atroshi and co-workers (2006) found similar results with improved radial length in the non-bridging group. As healing progresses there is presumably some resorption of bone, allowing an inevitable loss of radial length.

Volar malunion appeared to be more prevalent with non-bridging than with bridging external fixation, although the difference did not reach statistical significance. Volar malunion may occur in non-bridging fixation because there is direct control of the distal fragment, which allows the possibility of over-reduction of the fracture—especially in the presence of volar comminution. With care and awareness of the possibility of over-reduction, this is a preventable complication.

The scope of this study did not include functional outcome measures, as it was limited by being retrospective. However, previous studies (McQueen 1998, Flinkkila et al. 2003, Bednar and Al-Harran 2004, Uchikura et al. 2004) have demonstrated significantly improved functional outcomes paralleling the radiographic outcomes, although in one study this advantage was only in the short term (Atroshi et al. 2006). It would seem reasonable to assume similar improvement in functional outcomes in the present series, especially since the radiographic outcome measures are those that have been shown previously to correlate with function (Villar et al. 1987, Solgaard 1988, McQueen et al. 1996).

Pin pullout was rare in this series, with only one case in the non-bridging group and 3 in the bridging group. Non-bridging external fixation is used more commonly in older patients and in women who might be expected to be osteopenic. It appears that previous concerns that the osteopenic distal radius would not provide sufficient purchase for the pins are unfounded.

In this series, 60% of unstable fractures of the distal radius were suitable for non-bridging external fixation. The main factor that precludes its use is lack of space in the distal fragment, either because it is too small (less than 5 mm of volar cortex) or because in severe articular fractures the space is occupied by fixation for the joint surface. It is important to realize that in severe articular fractures, the non-bridging fixator will maintain metaphyseal alignment but articular alignment must be restored and maintained using adjunctive techniques. In reality, the presence of screws or wires rarely leaves sufficient space for distal pins, as evidenced by the very small proportion of AO type C3.2 fractures treated by bridging external fixation in this series. Young males are more likely to have severe intra-articular fractures (McQueen 2006), so for this reason the technique was used less in that group. One previous study (Krishnan et al. 2003) showed no radiographic or functional differences between the two types of external fixation for severe intra-articular fractures. This is not surprising, as the overwhelming influence on the outcome of intra-articular fractures is generally considered to be the initial articular damage rather than the method of fixation (Marsh et al. 2002). In addition, Krishnan et al. did not take full advantage of the reduction capabilities of the non-bridging technique, as they did not use the "joystick" technique and consequently found that "the degree of reduction did not fall within the limits defined as acceptable".

The overall complication rate for the 588 fractures was 38%. This is similar to published results for more complex or unstable distal radius fractures treated with external fixation (McQueen 2006). Excluding malunion, the rate in this series was 22%. With the exclusion of dorsal malunion, complications are similar for the two groups—apart from minor pin-track infections, which are more common in the non-bridging group. This is likely to be because of the movement of the skin around the pins, with mobilization of the wrist occurring during the period of fixation. Minor pin-track infections did not progress to an increase in major pin-track infections in the non-bridging group, and do not compromise the final outcome (McQueen et al. 1996, McQueen 1998).

Despite distal pin placement, extensor pollicis longus (EPL) rupture was no more common with non-bridging external fixation than with bridging fixation—with a rate of 1% in each group, which compares favorably with published rates of EPL rupture in a group of patients with distal radius fractures treated with a variety of operative and non-operative methods (McKay et al. 2001). It is important to use open pin placement techniques for the distal pins, to avoid damage to the EPL tendon. The low rate of tendon irritation or rupture is an advantage of external fixation techniques over dorsal plating, where high rates of tendon irritation or rupture have been reported (Ring et al. 1997, Rozental et al. 2003). With dorsal plating, patients frequently require re-admission for plate removal (Jupiter et al. 2002, Rozental et al. 2003) while external fixation is removed in an outpatient setting without the need for hospital admission or further anesthetic.

Volar locked plates have recently been introduced for the management of unstable distal radial fractures, but there is as yet a limited amount of data available on the results of this technique. It too requires a minimum amount of space in the distal fragment, and is likely to be used in cases similar to those treated by non-bridging external fixation. Early reports have documented rates of fracture collapse of up to 10% (Drobetz and Kutscha-Lissberg 2003, Rozental and Blazar 2006) and extensor tendon irritation or rupture in 7–16% of cases (Drobetz and Kutscha-Lissberg 2003, Rozental and Blazar 2006). As with dorsal plating, this leads to a not insignificant rate of secondary surgery. There is therefore a need for randomized controlled trials to compare the outcome of volar locked plates with that of non-bridging external fixation.

Contributions of authors

AH collected data and participated in the interpretation and analysis of data, and drafting of the manuscript. PD contributed to data collection and drafting of the manuscript. MMcQ was responsible for the conception and design of the study, and for critical revision of the manuscript.

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