Title
Dorsal bridging plates for the treatment of high and low energy distal radius fractures.

Authors
Tobias Roberts, MBBS BSc MRCS
ORCID: 0000-0002-7941-4956
Cezary Kocialkowski MBChB FRCS(T&O)
Alex Cowey MBChB FRCS(T&O) HanDipSurg(BSSH)

Institution
1) Royal United Hospitals, Combe Park, Bath, Avon, BA1 3NG

Correspondence
Tobias Roberts, Trauma & Orthopaedic Department, St. George’s Hospital, London, SW17 0QT
Tobiasrwroberts@gmail.com

Competing and conflicting Interests
None

Keywords
Dorsal Bridging plate, distal radius fracture, fixation, functional outcome, complex regional pain syndrome

1 Present address: T&O department, St. Georges Hospital, London, SW17 0QT
**Funding**

This research did not receive any specific grant from funding agencies in the public, commercial or not-for-profit sectors.

**Ethical review**

Ethical review was not required as this study was conducted under audit framework.
Abstract

Distal radius fractures are common and treatment of complex fracture patterns can be challenging. We assessed functional outcomes, radiographic analysis, and complications of 26 distal radius fractures treated with dorsal bridging plate (DBP) at a mean of 14 months post plate removal (6 – 34 months). Radiographic parameters were measured pre- and post-operatively and patient reported wrist evaluation scores, patient reported wrist range of movement and satisfaction scores. Mean post-operative total PRWE was 26 (range 0 – 76) and mean wrist mobility 52° flexion (range 10° to 85°) and 50° extension (range 10° to 85°). Mean post-operative patient satisfaction score was 89% (range 50 to 100%). Four patients developed complications (one EPL rupture and three developed CRPS). DBP can reliably restore distal radius anatomy and is associated with good functional outcome scores, return of functional range of wrist movement and high levels of patient satisfaction.

Level of Evidence: III
1. Introduction

The distal radius is the most commonly fractured bone in adults, forming a significant part of emergency department and orthopaedic workloads. These have a bi-modal distribution, affecting younger patients following high energy injuries and older individuals suffering low energy fragility fractures. (1) Prevalence is significantly greater in women than in men, and risk increases with age. (2) Indeed, the lifetime risk of distal radius fracture in women over 50 is estimated to be 15%. (3)

In fractures requiring surgical management, the goals of treatment are to anatomically reduce the fracture and maintain this with a stable construct that will allow bone healing and restoration of wrist function. (4) Popular fixation techniques have evolved over time. In the United Kingdom, since the publication of the DRAFFT study, there has been a shift towards fixation with Kirshner wires (K-wires) in dorsally displaced fractures. (5) For volarly displaced and intra-articular fractures, which cannot be reduced closed, volar plate fixation remains an effective mode of fixation. (6) Treatment of highly comminuted and unstable fracture patterns however remains challenging. (7,8)

Dorsal bridging plate (DBP) fixation has been described by several authors as an effective way to treat these fractures. (7,9–11) Not only does it allow restoration of the anatomy of the distal radius in these complex injuries, it has also been described to facilitate early post-operative weightbearing through the injured wrist in polytrauma patients. (12) The plate is inserted across the radiocarpal joint and fixed to the radius proximally and then to either the index or middle metacarpal, allowing indirect restoration and stable fixation of the wrist joint through ligamentotaxis. This method also avoids the risk of potential complications of pin-
site infection, loosening, breakage, neuropathies and skin compromise reported in external fixation. (13,14)

Published literature on DBP functional outcomes and complications remains limited to several retrospective case series and one prospective study. These show good rates of fracture union, and low rates of complications and acceptable functional outcomes. (7,9–11) The aim of this study was to assess the functional outcomes, radiographic analysis and complications of a case series of patients treated with dorsal bridging plate at our centre between 2018 and 2020, including during the coronavirus pandemic.

2. Methods

The trauma database at our institution, was reviewed and all patients with distal radius fractures, treated with DBP between 2018 and 2020 were identified. Electronic patient records (Millennium, Cerner EHR) were reviewed to identify demographic details, injury mechanism, operative details and complication rates. Patients were sent postal questionnaires to evaluate functional outcomes using the patient reported wrist evaluation (PRWE) score, post-operative range of movement using a visual chart and overall satisfaction using a visual analogue scale (VAS). Institutional approval for the study was obtained and ethical approval was not required as the study was conducted under audit framework.

Inclusion criteria were any adult 18 years or older who had undergone dorsal bridging plate fixation for distal radius fracture, including bilateral injuries, open and closed fractures and revision from previous failed fixation other than DBP.
Radiographs were reviewed using the Picture archiving and communication system (Fujifilm). Fracture classification was performed using the AO/OTA classification.\(^{(15)}\)

Volar tilt, radial inclination, radial height and ulnar variance were measured as described by Kreder et al.\(^{(16)}\) on pre-operative and post-operative radiographs after fracture union.

3. **Indications and surgical technique**

Indications for use of dorsal bridging plate was at the discretion of the Hand Surgery department and included multi-fragmentary and unstable distal radius fractures, open fractures, fractures where reduced bone quality would compromise surgical fixation and fractures that had failed alternative operative fixation techniques including K-wire or volar plate fixation. Operations were directly performed or supervised by consultant hand surgeons.

Surgical technique was standardised in approach as has been previously described.\(^{(12)}\) The dorsal capsule was not opened, and reduction of the fracture occurred indirectly through ligamentotaxis. Plate fixation was to either the index or middle metacarpal as per surgeon preference, with proximal fixation to the radius. The plate used was the DePuy Synthes (Warsaw, USA) 3.5mm 10, or 12 hole LCP metaphyseal plate. Fixation was with locking screws to create an ‘internal’ external fixator construct (Image 1). Standard postoperative treatment included immobilisation in a plaster for two weeks followed by additional support in a removable wrist splint. All patients commenced immediate hand therapy post-operatively, initially focussing on maintaining digit range of movement and subsequently concentrating on regaining wrist movement, after removal of the DBP.

4. **Results**

There were 26 dorsal bridging plates identified during the study period, performed on 21 women (one bilateral DBP) and four men. Of these, full follow-up data were available for 24
(in two patients post-operative care was transferred). The mean age at operation was 66 years (range 39 to 85). The mean ASA was 2 (range 1-3). Mean length of operation was 55 minutes (range 38 to 70).

There were 12 left wrists DBPs, 12 isolated right DBPs and one patient with bilateral DBPs. Twenty patients had isolated wrist fractures and in five patients the distal radius fracture was part of polytrauma. Polytrauma injuries included bilateral wrist fractures, pubic rami fracture, vertebral fracture and femoral condyle fracture. In eighteen cases (69%) the mechanism of injury was a low energy fall from standing height. In eight cases (31%) the mechanism was high energy including: falling from bicycle (3), road traffic accident (2), fall from height (2) and crush injury (1). Twenty three (88%) fractures were closed, and three (12%) were open.

In 24 cases DBP was the primary mode of fixation. Two were revisions from previous fixation – one K-wire fixation in which fracture position was lost and one volar plate that was removed due to deep wound infection. One DBP was performed following failure of non-operative management at 25 days. Stabilisation procedures in addition to the DBP included K-wire fixation of the radial styloid in 4 cases, and K-wire stabilisation of the ulna in 1 case. There were no intra-operative or immediate post-operative complications recorded.

The mean length of time from injury to primary DBP fixation was eight days (1 – 25). Plates were removed after a mean of 95 days (45 – 200). There was a negative correlation between days before plate removal and patient reported post-operative flexion and extension (p<0.05) i.e. longer durations were associated with reduced ROM. There was no correlation between duration of plate insertion and PRWE scores or patient satisfaction scores.
All fractures were intra-articular with 23 (88%) complete articular fractures (AO OTA C1-3) and three (12%) partial articular fractures (AO OTA B1-3) (Table 1).

Pre-operatively the mean sagittal angulation was 27° in a dorsally angulated fractures (range -1 to 59°) and 20.5° in volarly angulated fractures (range 11° to 23°). The mean radial inclination was 17.5° (range 8° to 27°). Mean ulnar variance (radial shortening) was 5.9mm (range -6.9 mm to 12mm). Post-operatively the mean sagittal angulation was 4.4° in a dorsally angulated fractures (range 1° to 15°) and 6.1° in volarly angulated fractures (range 1° to 20°). The mean radial inclination was 19° (range 12° to 26°). Mean ulnar variance was 0.7 mm (range -4.1 mm to 5.5 mm). (Table 2). Pearson correlation found no correlation between these post-operative radiographic parameters and PRWE scores (p<0.05).

PRWE scores were available for 22 fractures (85%) and were obtained at a mean of 14 months after plate removal (range 6 months to 34 months). The mean total PRWE was 26 (range 0 – 76). Within this, mean pain subscale was 15 (range 0 – 37) and function subscale was 11 (range 0 – 43.5).

Self-reported wrist mobility at the same time point was mean 52° flexion (range 10° to 85°) and 50° extension (range 10° to 85°). The mean post-operative patient satisfaction score was 89% (range 50 to 100%). Pearson correlation found no correlation between severity of fracture pattern and PRWE scores (p = 0.51).

Four patients (15%) developed post-operative complications. One patient sustained an extensor policis longus (EPL) tendon rupture, which was repaired at the time of DBP.
removal. Three patients developed complex regional pain syndrome (CRPS). This was diagnosed clinically by consultant hand surgeons in the hand clinic and included symptoms of continued pain and stiffness, altered skin colouration, shiny appearance to skin and abnormal hair distribution. All CRPS diagnoses occurred in women between the ages of 40 and 64 years and in patients who underwent primary fixation with a DBP. All cases were treated with urgent hand physiotherapy with resolution in two patients and ongoing symptoms in one patient. The degree of sagittal angulation in the CRPS cohort compared with the non-CRPS cohort was statistically significant (p<0.05) (Welch’s T-test). No other radiographic parameters were statistically significant.

5. Discussion

This study demonstrates that DBP is an effective treatment for restoring the anatomy of the wrist joint following complex intra-articular distal radius fractures. Radiographic analysis of the fracture patterns showed significant disruption of the normal anatomy, with marked dorsal or volar angulation and ulnar variance. This was corrected to within normally accepted parameters (17) in the majority of cases. The postoperative functional outcomes were also encouraging for restoration of function in this cohort. Published literature on DBP fixation for distal radius fractures is limited to mainly small retrospective case series and a small prospective study. To our knowledge only one other study has reported both clinical and radiological outcomes in a larger cohort of patients – with 33 patients included. (10) Their study reports outcomes in a similar cohort of patients, although they look specifically at patients over 60, with a mean age of 70 in their study. Our mean study age of 66 reflects the greater than 75% of the cohort over 60, and the preponderance of complex intraarticular wrist fractures that may not be amenable to conventional volar or dorsal plate fixation in this group. Combined with the likelihood of osteoporotic bone, these facts can be very
challenging to treat, with high rates of complication using the single plate techniques. (18) In our study, the decision to proceed with DBP primarily was following multi-consultant discussion and with consideration of the likelihood of significant difficulty or failure with other surgical techniques. It can also, as demonstrated here, be used effectively to manage other failed fixation methods – being successfully used up to 4 weeks after primary immobilisation or fixation had failed. We suspect that this is likely to be close to the upper limit of its useful time frame, as beyond this, indirect reduction through ligamentotaxis is unlikely to be effective due to healing around the fracture site.

The technique of indirect reduction through ligamentotaxis offers itself as a useful alternative when the complexity of the fracture pattern does not allow for percutaneous pinning alone. It also avoids the high complication rates of loosening, pin site infection and poor patient satisfaction that has been reported with external fixation of the wrist and which have led to decline in its use in recent years. (19) Similar rates of complex regional pain syndrome as those seen in our study have also been observed with use of external fixators. (20) Direct comparisons between the two techniques have not been published to our knowledge, and this could form the basis of a prospective trial in the future, although our results suggest that DBP can provide satisfactory outcomes in similar hard to treat fracture patterns, and without the complications reported with external fixation alone. (21)

Original studies using both goniometers, and more recently motion analysis using infrared cameras, have found the mean flexion and extension arc of the healthy wrist to be in the region of 130 to 140 degrees, with greater flexion than extension. (22,23) However, very little range of movement (ROM) is necessary to carry out activities of daily living. (24) Indeed personal care activities may require as little as 10° of flexion and 15° of extension.
Our study shows self-reported ranges of motion well within this functional range. This could explain the positive PROMs, even in those patients with a relatively reduced ROM. Furthermore, our radiological outcomes are similar to those reported by Richard et al. (10) although they only provide outcome data, but demonstrate restoration of palmar tilt to an average of 5° in all but two patients.

Complications were limited to one EPL tendon rupture, a known complication of distal radius fractures, and three patients (11.5%) who developed CRPS. Richard et al. (10) report a complication rate of 12% - one CRPS, one nerve injury, one infection and one patient with digital stiffness requiring tenolysis. Pathogenesis of CRPS is poorly understood, with multiple factors thought to be influential. These include neuropathic inflammation, autonomic dysregulation, genetic influences, psychological factors and risk factors such as female sex, fibromyalgia and rheumatoid arthritis. (26) The prevalence of CRPS following distal radius fracture is uncertain, with large population studies demonstrating rates below 1% (27,28), but also as high as 37%. (29–31) Women are reported to be two to three times more likely than men to develop CRPS, with those aged between 61 to 70 years at highest risk. (32,33) This was similarly reflected in our study. A meta-analysis analysing the risk of development of CRPS in surgically treated distal radius fractures found no difference in the method of fixation (34), although DBP was not included in this analysis. Interestingly, our study found a significant difference between the mean sagittal angulation in patients who developed CRPS compared with those that did not, suggesting that extremes in sagittal angulation may be associated with development of this condition and further work should focus on this.
Historical studies have stressed the importance of restoration of normal radiographic parameters and functional outcomes in distal radius fractures. Loss of volar tilt was shown to be associated with decreased grip strength (35), whilst radial shortening has been suggested as being the most important factor in loss of function. (36,37) More recently only restoration of volar tilt and radial shortening have been suggested as necessary to obtain good functional outcomes. (38) Restoration of radiographic parameters has not been found to be associated with better functional outcomes in patients over 60. (39) Further, correlation between restoration of normal radiographic parameters and restoration of function is controversial, with only weak correlations found between these and functional outcomes. (40) Our study supports the more recent views, finding no correlation between postoperative radiographic parameters and PRWE scores.

The coronavirus pandemic occurred around half-way through the study period. During its initial phases there was an emphasis on reducing in-hospital face-to-face contact where possible, as well as the reduction in capacity of orthopaedic operating. This resulted in several patients (23% of the study group) whose DBP remained in-situ for more than 100 days. This was accompanied by a reduction in post-operative face-to-face hand physiotherapy (patients were offered telephone consultations). Interestingly, whilst this is associated with a reduced ROM, this had no correlation with patient PRWE scores or overall satisfaction, suggesting that delays to plate removal do not significantly alter outcomes.

Limitations of the study include issues relating to reporting of range of movement. We only sought information on flexion and extension and did not obtain information on functional measures such as grip strength. Similarly, a control group (for instance measurements of the unaffected contralateral wrist) may have provided further useful data and insights into the
effects of DBP on wrist function. As we included bilateral injuries this was not possible, but such a design would improve a future study. Flexion and extension were self-reported by patients using a visual chart, which may have resulted in inaccuracy values compared to goniometric or surface marker measurement. However, it has been shown that there is no significant advantage in accuracy using a goniometer over visual assessment of wrist position by clinicians (41) and it is therefore likely that the self-reported ROM scores reported here are reliable. This is further corroborated by Richard et al. (10) paper which showed similar ROM results. Indeed, the functional outcome scores that complement this data, show excellent function post-surgery and we can therefore surmise that ROM is adequate to provide a good function for these patients. Alternative techniques such as the use of smartphones to aid patient self-reporting have been shown to be effective and could be employed in further similar studies. (42)

**6. Conclusions**

Dorsal bridging fixation is a safe and effective treatment for complex distal radius fractures, where other surgical fixation techniques may be unsuccessful. DBP is able to reliably restore distal radius anatomy and is associated with good functional outcome scores, return of functional range of wrist movement and high levels of patient satisfaction.

**7. References**

3. Cummings SR, Nevitt MC, Haber RJ. Prevention of osteoporosis and osteoporotic


23. Li ZM, Kuxhaus L, Fisk JA, Christophel TH. Coupling between wrist flexion-


32. de Mos M, de Bruijn AGJ, Huygen FJPM, Dieleman JP, Stricker BHC, Sturkenboom MCJM. The incidence of complex regional pain syndrome: A population-based study.


Table 1: frequency of fracture pattern by AO classification

<table>
<thead>
<tr>
<th></th>
<th>A) Partial Articular radius… (2R3B2)</th>
<th>A) with associated ulnar fracture (2U3A1)</th>
<th>B) complete articular radius… (2R3C1-3)</th>
<th>B) With associated ulnar fracture (2R3A1-3)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Count</td>
<td>1</td>
<td>3</td>
<td>8</td>
<td>14</td>
</tr>
</tbody>
</table>

Table 2: Pre- and post-op radiographic analysis

<table>
<thead>
<tr>
<th>Preop – (frequency) : mean [range]</th>
<th>Post-op</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sagittal angulation</td>
<td></td>
</tr>
<tr>
<td>• Dorsal (22) : 27° [1° - 59°]</td>
<td>Dorsal (7) : 4.4° [1° to 15°]</td>
</tr>
<tr>
<td>Radial inclination (26) : 17.5° [8° - 27°]</td>
<td>Neutral (1) : 0°</td>
</tr>
<tr>
<td>Ulnar variance</td>
<td>Ulnar variance</td>
</tr>
<tr>
<td>• +ve (23) : 6.6mm [1.9 – 12]</td>
<td>+ve (7) : 3mm [1 – 5]</td>
</tr>
<tr>
<td>• -ve (1) : 6.9mm</td>
<td>-ve (1) : 4.1mm</td>
</tr>
<tr>
<td>• Neutral (2)</td>
<td>Neutral (16)</td>
</tr>
</tbody>
</table>
Image 1. Pre-operative, immediate post-operative and post fracture union radiographs of complete articular fracture treated by dorsal bridge plating.
Declaration of interests

☒ The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

☐ The authors declare the following financial interests/personal relationships which may be considered as potential competing interests: