“Sandwich” Plating for Intra-articular Distal Radius Fractures with Volar and Dorsal Metaphyseal Comminution

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Abstract

Introduction Intra-articular distal radius fractures with volar and dorsal comminution present a special challenge to the hand surgeon.

Methods Ten patients formed the study cohort. All plates were low profile and stainless steel. Radiographic parameters, range of motion, and strength compared to the uninjured side were recorded. Functional outcome was evaluated by Disabilities of the Arm, Shoulder and Hand (DASH) questionnaire and Gartland and Werley scoring system.

Results Median age at surgery was 58 years (range, 24 to 86). Mean follow-up was 17 months (range, 12 to 28). According to the AO classification system, there were three type C2 and seven type C3 fractures. Median preoperative dorsal angulation was 24 deg; median postoperative dorsal angulation was 3 deg. Eighty percent (8) of the fractures also had an intra-articular step-off or gap, all of which were corrected to neutral by the procedure. Compared with the contralateral side, mean extension and flexion were 73 and 75%, respectively, pronation and supination were 95 and 88%, respectively, and grip strength and thumb pinch were 72 and 87%, respectively. Mean postoperative DASH score was 16 points, and 70% (7) of the patients had Gartland and

Werley scores of *good* or *excellent*. None of the patients needed to have their plates removed, and no extensor tendon rupture was reported.

Conclusions The “sandwich” plating technique is an effective method of regaining near-anatomic reconstruction of intra-articular, volarly and dorsally comminuted distal radius fractures. Results from this study demonstrate that patients can expect to regain about 80% of their range of motion and strength. Moreover, 70% of the patients will have *good* to *excellent* functional outcomes. This is the first study to examine range of motion and functional outcome of low-profile “sandwich” plating without plate removal.

Keywords Distal radius fracture · Combined dorsal and volar plating · Low-profile plating

Introduction

Intra-articular distal radius fractures with both volar and dorsal comminution present a special challenge for the hand surgeon. These fractures are more commonly seen in the elderly osteoporotic patient or in the younger patient as a result of high-energy trauma. The extensive comminution on the dorsal and volar aspects of the wrist complicates the proper restoration of distal fragments using traditional management techniques, such as external fixation or single plating from the dorsal or volar surface of the wrist. This challenging fracture pattern is likely to result in loss of alignment with any of these treatment modalities alone.

Multiple treatment options have been entertained to treat these difficult fractures. External fixation has been a standard treatment choice, although fractures tend to collapse even with the use of Kirschner wires and/or bone grafting [1]. Fracture fragments often displace to the side

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opposite an isolated dorsal or volar plate, leading to subsequent malunion or the need for reoperation in this population of patients. Although the use of distraction plating [2], combined external and internal fixation [3, 4], and wrist fusion [4] have all been described, no single technique has proved adequate in the management of this subset of complex fractures.

A relatively unique treatment option is combined dorsal and volar plating, or the “sandwich” plating technique. The concomitant use of these plates on both surfaces of the wrist can control the articular fragments by compressing them together while buttressing any displaced dorsal or volar metaphyseal fragments. However, the additional implanted hardware increases the required operative time and the need for tissue dissection. It may increase the risk of tissue ischemia, infection, and subsequent poor bone healing. The use of dual plating also involves the theoretical risk of compromised range of motion secondary to increased wrist stiffness.

The use of sandwich plating as a technique for treating this group of fractures has been examined by only one other study [5]. Functional outcome was assessed only after nearly all of the patients had their plates removed. Additionally, the plates used in that study were not low profile. The purpose of this study was to determine the functional outcome, radiographic alignment, and complications of combined low-profile dorsal and volar plating for this subset of complex distal radius fractures without plate removal. Our hypothesis is that sandwich plating, using a low-profile plating system, can provide stable mechanical fixation while reducing the occurrence of tendon complications and mitigating the need for plate removal.

Materials and Methods

The patient records, operative reports, and radiographs of 12 consecutive patients from 2002 to 2004 who underwent combined dorsal and volar plating at our institution caused by unstable intra-articular fractures of the distal radius were retrospectively analyzed for this study. Patients with less than 12 months of follow-up were excluded from the study. Other exclusion criteria of bilateral, upper extremity injuries or concomitant external fixation resulted in the loss of two patients from the initial cohort of 12. All patients were specifically called back for final functional evaluations. Research protocols were approved by the Institutional Review Board at our institution, informed consent was obtained, and all patient information was protected under HIPAA guidelines.

The 10-person study group included one man and nine women, with a median age of 58 years (range, 24 to 86 years; Table 1). The median duration of follow-up was

Table 1 Patient cohort.

Patient Records of the 10-Person Study Group	
Age, years	
Median (range)	58 (24–86)
Gender	
Female	9 (90%)
Operation on dominant hand	5 (50%)
AO classification	
C2	3 (30%)
C3	7 (70%)
Follow-up, months	
Mean (range)	17 (12–28)

17 months (range, 12 to 28 months). Five of the patients were operated on their dominant hand. The mechanism of injury was a simple fall from standing height for three patients, a high energy fall for five patients (including a fall on ice for three patients, a fall during a stampede for one patient, and a fall off a horse for one patient), and a motorcycle accident for two patients. One patient sustained an open book pelvic fracture at the time of injury, and another patient had accompanying fractures of the femur and tibia and tears of the anterior cruciate and medial collateral ligaments.

Surgical Technique

All patients initially were treated with closed reduction and splinting in the emergency room for pain control purposes. All patients were taken to the operating room for definitive open reduction and internal fixation by a single fellowship-trained orthopaedic hand surgeon within 10 days after the injury. All plates were anatomically designed, low profile (1.2 mm dorsal, 1.5 mm volar in thickness), and stainless steel (Wright Medical, Arlington, Tennessee, USA). Implant size was determined by the operating surgeon. All plates used on the dorsal surface were standard, non-locking. Seven patients received standard, non-locking volar plates, whereas the remaining three received locking volar plates.

According to the AO classification system conducted by independent radiographic review, there were 10 type C fractures (including three type C2, and seven type C3 fractures; Fig. 1). Dorsal and volar cortical comminution is confirmed immediately before surgery via fluoroscopy (Fig. 2). Fractures are first exposed volarly by the modified Henry’s approach. A longitudinal 8-cm incision is made over the flexor carpi radialis (FCR) tendon of the distal volar aspect of the wrist. The FCR tendon sheath is incised, and the FCR tendon is retracted ulnarly. The dorsal FCR sheath is then incised, and a superficial blunt retainer is used between the incised FCR tendon sheaths. The radial

Figure 1 **a** Anterior–posterior and lateral preoperative views displaying intra-articular fracture with both dorsal and volar comminution. **b** Axial and sagittal computed tomography reformations of the same patient in **a**.

FCR sheath protects the radial artery, whereas the ulnar FCR sheath protects the median nerve.

Once this is done, blunt dissection is carried down to the pronator quadratus muscle. The flexor pollicis longus (FPL) tendon and part of its muscle insertion are reflected ulnarly. The blunt, curved self-retainers are then placed in the deeper interval between the FPL tendon and the brachioradialis tendon. Once this is done, the pronator quadratus is incised and then reflected off the radius. The comminuted volar metaphyseal fracture site is visualized and pulled out to length with longitudinal traction. Therefore, the bayoneted volar cortical fragment is reduced before volar plate placement. A locking or non-locking low-profile volar T-plate is then secured to the radial diaphyseal bone using a single 3.5-mm bicortical screw placed proximally. This volar plate serves as a buttress for the volar fragments of the fracture and prevents volar displacement when the fracture is reduced from the dorsal side. Proximal fixation of the volar plate is checked under fluoroscopy (Fig. 3).

With the volar buttress plate in place, an 8-cm incision is made over the dorsum of the wrist just ulnar to Lister's

Figure 2 Fluoroscopy demonstrating comminution of both the dorsal and volar metaphyseal cortices.

Figure 3 Intraoperative fluoroscopy displaying fixation of low-profile volar plate in both anterior–posterior and lateral views. All intraoperative images are from the same patient.

tubercle. Dissection is carried down to the extensor tendons. The extensor tendon sheath is incised just ulnar to Lister's tubercle. The extensor pollicis longus (EPL) tendon is isolated and retracted radially. The dissection is then carried down to the bone, exposing the distal radius through the interval between the second and fourth extensor compartments. This incision is carried distally through the dorsal capsule of the carpal bones as well, exposing the

Figure 4 Anterior–posterior and lateral intraoperative fluoroscopic views demonstrating placement of volar and dorsal plates.

entire articular surface for direct visualization of any articular incongruities. An appropriately sized low-profile dorsal T-plate is then placed, and 3.5-mm unicortical screws are placed proximally to compress and hold the dorsally comminuted metaphyseal fragments. The metaphyseal reduction with both plates held proximally is verified in both anterior–posterior and lateral views under fluoroscopy (Fig. 4).

With the metaphysis supported both dorsally and volarly, attention is then turned to the articular surface. The dorsal and volar articular fragments are reduced using bone reduction forceps and may be temporarily stabilized with small 0.035-inch Kirschner wires. Any residual defect in the metaphysis after reduction of the articular surface is packed with cancellous bone allograft. Subsequently, appropriately sized 2.7-mm bicortical screws are placed through either the volar or dorsal plates depending on the mechanical fixation of these fragments. Once the articular surface fragments are stabilized, two more unicortical screws are placed proximally through the dorsal and volar plates (Fig. 5). The extensor retinaculum is then repaired dorsally, leaving the EPL out of its sheath. Relaxing incisions may be needed on the retinaculum for its closure. This is determined intraoperatively based on how well the retinaculum can be closed over the implant; it is not specific to the sandwich technique and is used elsewhere in the general dorsal approach. The fascia of the pronator quadratus is then repaired. Skin is closed using subcutaneous and subcuticular stitches.

Dorsal short-arm splinting is used after surgery to ensure adequate wrist stabilization and to still allow full flexion of all five fingers. Patients are advised to begin active and passive finger motion early in the postoperative period.

Figure 5 Intraoperative fluoroscopy displaying dorsal and volar plate fixation initially secured by two unicortical screws through each plate confirmed in both anterior–posterior and lateral views.

Table 2 Range of motion compared with contralateral side (%).

ROM Variable	Mean	95% CI
Extension	72.9	61.9–84.0
Flexion	74.5	60.8–88.3
Pronation	95.4	91.5–99.3
Supination	87.5	77.0–98.0
Grip strength	71.6	55.2–87.9
Thumb pinch	87.1	72.0–97.9

CI confidence interval

Two weeks after surgery, the sutures are removed and the wrist is placed in a custom-made thermoplastic volar splint. Active and active-assisted motion of the wrist is started at that time. Passive motion of the wrist and grip-strengthening exercises are started at four weeks. Based on evidence of radiographic fracture healing, light weight-bearing exercises and static progressive/dynamic wrist strengthening are begun at 4–5 weeks.

Evaluation

At the time of the call-back evaluation, the range of motion of the operated wrist was evaluated by recording the arcs of flexion–extension, pronation–supination, and radial and ulnar deviation with a standard goniometer and was compared with that of the uninjured, contralateral side. Grip strength and thumb pinch were measured with a dynamometer and thumb press, respectively, and were compared with that of the contralateral side (Baseline range-of-motion kit, Fabrication Enterprises, Inc., Irvington, New York, USA). Radiographic data were evaluated by two independent reviewers for angulation, articular congruity, and radial height/ulnar variance. Fractures were classified according to the AO classification system. Radiographic healing was defined as union of the fracture within six months.

Activities of daily living and quality of life were assessed with the Disabilities of the Arm, Shoulder and Hand

(DASH) questionnaire [6] and the Gartland and Werley clinical scoring system [7]. Any postoperative complications, including loss of reduction, nonunion, infection, pain, plate removal, hardware removal, neuropathy, or extensor tendon irritation or rupture were recorded.

Continuous variables were assessed for normality by the Kolmogorov–Smirnov test to determine the appropriate statistical methods. Radiographic parameters did not follow a normal distribution, and therefore were presented as medians, and changes between preoperative and follow-up were evaluated by the Wilcoxon signed-ranks test for paired analysis [8]. Functional outcome scores (DASH and Gartland and Werley) conformed to a Gaussian (bell-shaped curve) distribution and were presented in terms of the mean and standard deviation. Range-of-motion variables were expressed as a mean percentage compared with the contralateral side, and 95% confidence intervals were determined using a paired *t* test to define the expected motion postoperatively, relative to the opposite side [9]. Because the number of patients was small and range-of-motion variables were skewed, the Spearman rho correlation coefficient was used to measure the association between continuous variables, including age, follow-up, range-of-motion variables, and functional outcome scores. Multiple regression analysis was used to identify which variables were predictive of DASH and Gartland and Werley scores by examining the following covariates: age, gender, operation of dominant hand, AO classification, duration of follow-up, range of motion variables on injured side and compared to the contralateral side, and radiographic parameters. Statistical analysis was performed using the SPSS software package (version 14.0, SPSS, Inc., Chicago, Illinois, USA). Two-tailed values of $p < 0.05$ were considered statistically significant.

Results

The mean range of motion of the wrist at time of follow-up consisted of 46° (range, 30 to 72°) of extension, 46° (range,

Table 3 Changes in radiographic parameters.

Radiographic parameter	Median (Range)		<i>p</i> value (Wilcoxon test)
	Preoperative	Follow-up	
Dorsal angulation (°)	24 (–2, 39)	3 (–4, 13)	<0.01 ^a
Step-off (mm)	0 (0, 3)	0 (0, 1)	0.04 ^a
Gap (mm)	3 (0, 7)	0 (0, 1)	<0.01 ^a
Radial height/ulnar variance (mm)	1 (0, 7)	0 (0, 3)	0.08 ^b

Angulation defined in reference to initial dorsal angulation: dorsal (+), volar (–).

^a Statistically significant

^b Trend

30 to 60°) of flexion, 80° (range, 70 to 90°) of pronation, and 71° (range, 40 to 86°) of supination (Table 2). The mean grip strength was 20 kg (range, 6 to 30 kg), and the mean thumb pinch was 7 kg (range, 4 to 13 kg).

Pre- and postoperative radiographs were analyzed for the following parameters: angulation, step-off, gap, and radial height/ulnar variance (Table 3). Postoperative angulation was defined in reference to preoperative dorsal angulation [i.e., dorsal (+), volar (-)]. Satisfactory radiographic reduction (within 10° of dorsal angulation [10], 20° of volar angulation [11], <5 mm of positive ulnar variance [12], and <1 mm of articular incongruity [13]) was achieved for all but one patient whose postoperative dorsal angulation was 13°. Postoperative radiograph at 8 weeks is shown in Fig. 6. There was a significant difference between mean preoperative dorsal angulation of 24° and mean postoperative dorsal angulation of 3° ($p<0.01$).

The mean score on the DASH questionnaire was 16 points (range, 0 to 50 points; maximum possible score, 100 points; Table 4). According to the Gartland and Werley scoring system, three patients had an *excellent* outcome, four patients had a *good* outcome, two patients had a *fair* outcome, and one patient had a *poor* outcome (mean score, 7.4; range, 1–28).

Several range-of-motion measurements (using percentage compared with the contralateral side) were correlated with functional outcomes. Extension was inversely correlated with both DASH score (Spearman $\rho=-0.76$, $p<0.01$) and Gartland and Werley score. Thumb pinch was also significantly correlated with both DASH and Gartland and Werley scores (Spearman $\rho=-0.70$, $p=0.02$). Grip strength was correlated with DASH score (Spearman $\rho=-0.70$, $p=0.02$) but not with Gartland and Werley score ($\rho=-0.27$, $p=0.45$). Pronation was positively correlated with DASH score ($\rho=0.65$, $p=0.04$), although the association did not reach significance with Gartland and Werley score ($\rho=0.51$, $p=$

Figure 6 Eight-week postoperative anterior–posterior and lateral radiographs displaying stable sandwich plate fixation.

Table 4 Functional outcomes.

Functional Outcome Scoring System	Mean $\pm$ SD	Median (Range)
DASH (points)	15.6 $\pm$ 14.8	8.6 (0, 50)
Gartland and Werley (points)	7.4 $\pm$ 8.0	5 (1, 28)

0.13). Neither flexion nor supination was correlated with either of the functional measures.

Complications were catalogued throughout the course of the study period and at time of follow-up evaluation. After an average follow-up of 17 months, there was no malunion, plate breakage, infection (early or late), or compression neuropathy. No plates were removed for soft-tissue complications, and there were no flexor or extensor tendon ruptures. Carpal tunnel decompression was performed on one patient strictly based on preoperative symptoms (i.e., not for prophylactic reasons).

None of the patients experienced residual motor or neurological deficits. One patient with poor functional outcome and resulting elevated DASH and Gartland and Werley scores was additionally diagnosed to have severe cubital tunnel syndrome at the elbow by electromyography/nerve conduction tests. No preoperative electromyography/nerve conduction data were available. The patient's symptoms of hypersensitivity in the ring and small finger began approximately 5 months postoperatively. It was therefore determined that this patient's poor functional outcome and limited hand range of motion were due to a condition most likely unrelated to surgery.

Discussion

The severity of injury and resulting fracture pattern complicates the treatment of intra-articular distal radius fractures with dorsal and volar comminution. Various forms of treatment have been employed for management of complicated and severely comminuted distal radius fractures, including combined external and internal fixation [3, 4] and even wrist arthrodesis [4]. Articular fragments have little support when there is accompanying metaphyseal comminution [1, 14]; some studies have proposed temporary plate fixation across the wrist joint as a solution [2, 15]. Although there has been a recent operative trend to volar plate fixation in the management of distal radius fractures [16], this approach may not be adequate for severe type C fractures. More recent work has shown that isolated fixed-angle volar plating for unstable dorsally displaced fractures may result in fracture collapse [17].

Whereas other studies have examined a similar group of complex distal radius fractures, the use of a single sandwich

plating technique is rarely used. Bass et al. [3] focused on the treatment of C3 type fractures from both a dorsal and volar approach. However, this approach used smooth wires as well as plates or screws for certain fractures. It also included external fixation use for an average of ten weeks. Rogachefsky et al. [4] also used external fixation in combination with dorsal and/or volar plating. Another study by Fitousi et al. [18] examined type C1, C2, and C3 distal radius fractures. Combined dorsal/volar plating was used only 35% (12/34 patients) of the time. The remaining patients received either single plate fixation or Kirschner wires. An alternative approach was employed by Ruch et al. [2] who used distraction plating to manage patients with severe comminution.

These studies have produced a wide range of functional outcomes, including 45–65° for extension, 47–60° for flexion, 64–88° for supination, 68–82° for pronation, and 69–83% for grip strength compared to the contralateral side. Moreover, complication rates were as high as 26% [18]. These complications included problems with infections at the surgical site [2], infections at the K-wire site [3, 4, 18], extensor lag and rupture [2, 18], median neuropathy [18], and wrist collapse leading to fusion [4].

It has been difficult to extrapolate applications about the different fracture management options from any one type of the above fixation techniques. This is because of the heterogeneity of treatments used, hardware choices, and postoperative management. The only study in the literature dedicated to combined dorsal and volar plating evaluated a series of fractures with significant articular and metaphyseal components [5]: group C3.2 fractures according to the comprehensive classification of fractures [19]. Twenty-one of the 25 patients in the study required plate removal; the authors do not state how many removals were caused by pain, stiffness, or surgeon preference. The average time before plate removal was also not mentioned. The authors justify the removal of plates because of the severity of injury. Thus, the range of motion, strength, and functional outcomes were assessed only after plate removal in these patients. For most patients, data were not collected with the plates in situ. Two patients required a carpal tunnel release at the time of plate removal, which can further obscure the above outcomes data. More than half of the patients had concomitant external fixation for intraoperative distraction. Distraction was used in four patients in the postoperative period for variable amounts of time, which also raises the likelihood of pin-site infection.

The above sandwich plating study included six patients who had a prior operation, including external fixation or isolated dorsal plate fixation. It is unclear how this particular group of patients fared compared to the other patients in the cohort. Moreover, the authors do not stratify their outcomes data according to specific plate type used, as multiple plate

types were used, including the Synthes Pi plate and Synthes T-plate (Synthes, Inc., Paoli, Pennsylvania, USA). An advantage of this study is the use of a single plating system.

Complications cited by Ring et al. [5] in their report included two cases of tendon ruptures requiring reconstruction: a volar FPL tendon and a dorsal EDC tendon. The plates used in the study were of traditional thickness (2.0–3.5 mm in thickness). Thicker, traditional plates can alter tendon excursion, causing complications requiring plate removal and/or tendon repair. Our study uses a new generation of low-profile plates, which has been previously shown to reduce extensor tendon complications [20, 21].

Range of motion and strength measurements from this sandwich plating study are similar to that conducted by Ring et al.: average functional outcomes recorded were 51° of flexion, 54° of extension, 79° of pronation, 74° of supination, and a grip strength that was 78% of the contralateral side. The main difference between patient cohorts is that none of the patients in this study had their plates removed. Despite stable fixation, both patient surveys and range-of-motion assessments in our study demonstrate a need for improving dorsiflexion to enhance functional outcome.

This complex group of fractures challenges commonly used fracture classification systems. The AO classification system, for example, is not specific enough in its description of metaphyseal fracture components, especially in group C2 fractures. We contend that a key indication for sandwich plating is a multifragmented metaphysis with involvement of dorsal and volar cortices, regardless of the degree of disruption of the articular surface. Therefore, a group C2 fracture with multifragmented metaphysis, in our opinion, is just as strong an indication for combined plating as a group C3 fracture. All fractures in our study were intraarticular with significant dorsal and volar metaphyseal involvement. Although the comprehensive classification of fractures includes type C fracture groups with a multifragmented metaphysis, it does not specifically describe fractures with dorsal and volar metaphyseal comminution. Components of volar/dorsal comminution of the metaphysis as the basis for a fracture classification group have been described only by Trumble et al. [22].

The sandwich plating technique in this study allowed our patients to regain near-normal radiographic parameters. Based on Gartland and Werley scoring system, 70% will have *good* or *excellent* functional outcomes (at greater than 12 months) with minimal impairment in activities of daily living. Based on this study, patients with complex distal radius fractures managed with low-profile sandwich plating can expect to regain about 80% of their range of motion and strength. In our one patient with severe ulnar neuropathy, we cannot completely exclude the possibility of this being caused by the operation. However, both the

time-course of symptoms and nerve conduction testing results suggest another cause, as well as localization to the elbow rather than the wrist.

This study possess limitations. All the operations were done within one institution under a single surgeon; we hope to enlarge the scope of the study to test the sandwich plating technique over a larger cohort in multiple centers. Because no studies exist using combined dorsal and volar *low-profile* plates, there is no comparative data to traditional management. Although the Gartland and Werley system has been criticized as less stringent when compared to other scales, such as the modified Green and O'Brien system, we used it for ease of comparison to prior studies. Finally, this retrospective study involves a small sample size as a result of the relatively infrequent nature of the injury. Despite these limitations, this study plays an important role in the management of complex distal radius fractures and supports indications for this novel technique.

The sandwich plating technique is an effective method of regaining near-anatomic reconstruction of intra-articular, volarly and dorsally comminuted distal radius fractures. Approaching the wrist from both sides affords direct access and control over all major fragments to establish stable, mobile fixation of these complex distal radius fractures. Using low-profile stainless steel plates, no plate removals were necessary, and patients experienced no tendon complications. This is the first study to examine range of motion and functional outcome of low-profile sandwich plating without plate removal.

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