Outcome following distally locked volar plating for distal radius fractures with metadiaphyseal involvement

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Abstract

Background The surgical treatment of metadiaphyseal distal radius fractures may be difficult due to the associated articular or periarticular extension that limits standard fixation techniques. Longer distal radius volar locking plates allow stable fixation of the distal fragments while providing standard plate fixation in the proximal radius. We hypothesize that this plating technique allows adequate fixation to both the distal radius and metadiaphyseal fragments. The purpose of the study is to describe the outcomes, radiographic parameters, secondary surgeries, and complication rate with this device.

Methods A retrospective chart review was conducted on adult patients with a distal radius fracture and metadiaphyseal involvement treated with a volar, distally locked plate. All patients were followed up for radiographic union, with a mean time of 219 days (range 38–575). Fracture patterns, outcomes of range of motion, grip strength, and complications, as well as injury, post open reduction and internal fixation (ORIF), and finally, healed radiographic parameters were recorded.

Results Twenty patients with 21 fractures were included. At union, mean radiographic parameters were the following: volar tilt of 8°, radial inclination of 27°, radial height of 14 mm, and ulnar variance of −1 mm. The mean final range of motion was 52° flexion, 50° extension, 68° pronation, and 66° supination. Complications included one infection and one plate removal. Four patients developed a nonunion requiring secondary procedures. There were no incidents of hardware failure or adhesions requiring tenolysis.

Conclusion Distally locked long volar plating for metadiaphyseal distal radius fractures is a safe and effective treatment option for these complex fracture patterns allowing anatomic restoration of the radial shaft and distal radius.

This research was performed at the Mayo Clinic, Rochester, MN, USA.

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Introduction

Fractures of the distal radius with intra-articular or juxta-articular involvement and extensive metadiaphyseal comminution present a difficult management problem. Historically, external fixation was commonly used to manage these difficult and extensive fracture patterns [8, 22]. However, problems with a union of the metaphysis to the diaphysis have been described [22]. While previous volar, distal radial plates have had the ability to adequately control both intra-articular and/or juxta-articular fracture fragments [15, 17], their shaft length was not adequate to control both the articular surface and span extensive metadiaphyseal comminution while accommodating a typical radial bow. Other techniques, such as stacked plating [3, 13] and bridge plating [1, 6, 7, 18] have been recently described in an attempt to treat these difficult fractures; however, these techniques may utilize multiple plates and, at times, necessitate a secondary surgery for hardware removal [1, 6, 7, 18].

With the introduction of longer volar plates, adequate fixation and control of both the distal and metadiaphyseal fragments is possible. These longer plates provide good fixation of the articular pieces and, with a longer "shaft" component, the ability to secure the metaphysis to the diaphysis

while accommodating the natural radial bow. With these plates, the metadiaphyseal comminution can be bridged, if necessary, allowing fixation and restoration of the distal articular surface and secure fixation to the proximal radial shaft. The purpose of the study is to describe the outcomes, radiographic parameters, secondary surgeries, and complication rate with this device.

Materials and Methods

An institutional review board-approved retrospective review was conducted at our institution and identified patients with radial metadiaphyseal fractures, with or without intra-articular extension, that were treated with long volar locking plates (Hand Innovations, Biomet, Warsaw, IN). Inclusion criteria were patients that were at least 18 years old and had fractures with metadiaphyseal involvement with juxta-articular or intra-articular extension. All fractures must have had definitive operative fixation with a distally locked long volar locking plate. Patients who are unable to follow up for clinical and radiographic union were excluded. Twenty-five fractures in 24 patients were identified for review, three were excluded due to short follow-up, and one patient died due to unrelated complications prior to union, leaving 21 fractures (20 patients) for analysis. The group consisted of 12 males and 8 females with a mean age of 48 (20–72) years. Fractures occurred in 14 right wrists and 7 left wrists. The average time to definitive operative fixation was 3 (0–24) days.

The fractures were classified as open or closed according to the Comprehensive Classification of Fractures of Long Bones [14], specific for the epiphyseal region of the radius. Associated elbow injuries, scaphoid fractures, Galeazzi fractures, ulnar styloid fractures, distal ulna fractures, and other body system injuries were also recorded. Initial radiographs revealed five (24 %) A2, four (19 %) A3, five (24 %) C2, and seven (33 %) C3 fractures. Six (29 %) were open injuries, and 15 (71 %) were closed injuries. The nine (43 %) type A fractures had juxta-articular involvement with extensive metadiaphyseal comminution requiring distal and shaft fixation that was not amenable to a straight, nonspanning, plating system. Two patients (10 %) had concomitant elbow injuries, 2 (10 %) had scaphoid fractures, 6 (29 %) had Galeazzi fractures, 12 (62 %) had ulnar styloid fractures, 4 (19 %) had distal ulna fractures, and 14 (67 %) had injuries in the other body systems.

Treatment of the fractures included delayed open reduction and internal fixation (ORIF) after external fixation or primary ORIF with or without supplemental external fixation. The plate was centered over the radial shaft, utilizing the prefabricated bow to help restore the radial shaft anatomy. Primary bone grafting at the time of fixation or secondary bone graft procedures, as well as any acute carpal tunnel release or need for soft tissue coverage, were noted.

Immediate external fixation with later conversion to volar plating was performed in 4 (19 %) fractures, and open reduction and internal fixation was performed in the remaining 17 (81 %) with three of those (14 %) utilizing supplemental external fixation for support. Carpal tunnel release due to acute or imminent carpal tunnel syndrome was performed in two (10 %) fractures. Skin coverage was required in four (19 %) fractures. Of those, three (75 %) split thickness skin grafts were performed in two males for a degloving injury (open type A) and extreme swelling that could not be closed primarily (closed type C) and in one female who received fasciotomies for impending compartment syndrome (closed type C). The remaining patient (25 %) was a male requiring a serratus flap and splint thickness skin graft for a grade IIIC open type C fracture.

Primary bone grafting was performed at the time of volar fixation in seven (33 %) fractures, three (43 %) type A fractures and four (57 %) type C fractures. Five (24 %) fractures had bone graft applied at both the articular fracture and the metadiaphyseal comminution, and two (9 %) had bone graft applied only to the site of the metadiaphyseal comminution. The choice of primary bone grafting was made at the time of surgery depending on the level of comminution and bone contact obtained after fixation. Primary bone graft included iliac crest autograft in four of seven cases (57 %), femoral head allograft in one (14 %) and DBX Putty (DePuy Synthes, Paoli, PA) in two (29 %).

All fractures were followed up for clinical and complete radiographic healing. Clinical fracture healing was determined when the fracture site was nontender to palpation. Radiographic union was defined as complete obliteration of the fracture plane on multiple (AP, lateral, and oblique) radiographs. Patients with fractures requiring secondary procedures for bone grafting were reviewed for the time from original surgery to bone grafting, time from bone grafting to union, and total time from operative fixation to final union. Grip strength (kilograms) using a Jamar hydraulic hand dynamometer in position 2 (Lafayette Instrument Company, Lafayette, IN) and percent of contralateral grip, wrist flexion, wrist extension, forearm pronation, and forearm supination using a goniometer (degrees) were measured at the last clinic visit.

Radiographic volar tilt, radial inclination, radial height, and ulnar variance were measured [12] at the time of initial presentation (injury), after ORIF, and at final follow-up in all fractures. Volar tilt was defined as (+) when the articular surface faced volarly and (−) when the articular surface faced dorsally (dorsal angulation). Ulnar variance was defined as (−) when the ulna was shorter than the radius.

Complications including implant failure, tenolysis, infection, and carpal tunnel syndrome and the necessity for secondary procedures including nonunions requiring additional bone graft or hardware removal were identified. Postoperative carpal tunnel syndrome was defined as a new onset of

paresthesias in the median nerve distribution or worsening of any remote preexisting symptoms after volar fixation of the fractures.

Continuous data were reported with a mean, a range, and a standard deviation (SD) as appropriate. Radiographic volar tilt, radial inclination, radial height, and ulnar variance from initial injury to final follow-up was compared with paired Student's t tests, assuming significance with $p<0.05$. All calculations were performed utilizing Microsoft Excel (version 12; Microsoft Corporation, Redmond, WA).

Table 1 Outcomes at the time of final follow-up

	Mean	Range	SD
Grip (kg)	22	6–32	8
Grip (%)			
Contralateral	62	27–105	24
Flexion (°)	52	30–80	13
Extension (°)	50	25–70	14
Pronation (°)	68	35–90	18
Supination (°)	66	15–90	18

SD standard deviation

Results

All fractures were followed up for union with a mean time of 216 days (38–575, SD 134). Those fractures treated without secondary bone graft healed in a mean of 174 days (38–357, SD 81). Secondary bone grafting was performed at a mean of 253 days from injury in four (19 %) fractures with evidence of nonunion to assist in union. All eventually healed at a mean time of 124 days (49–169, SD 52) after bone grafting and a mean time of 377 days from initial injury (147–575, SD 199). Two of the four (50 %) patients requiring secondary bone graft for nonunion were closed A3 fractures originally treated with immediate ORIF and iliac crest bone graft; one of the four (25 %) fractures was a closed A2 fracture treated with ORIF alone; the last one was an open C3 fracture treated with initial external fixation, converted to ORIF with iliac crest bone graft, serratus free flap, and split thickness skin grafting. All secondary bone graft procedures were iliac crest autograft applied to the metadiaphysis. Of the four cases requiring skin coverage, only one (25 %) fracture, an open type C as above, required secondary bone graft. At the time of secondary bone grafting, no fracture demonstrated loose hardware requiring revision.

The average grip strength was 22 kg (6–32 kg, SD 8) in 10 fractures (10 patients), which was 62 % (27–105, SD 24) of the contralateral side. Final wrist flexion and extension were measured in 15 wrists, and pronation and supination were measured in 21 wrists. The average flexion was 52° (range 30°–80°, SD 14°), extension 50° (25°–70°, SD 14°), pronation 68° (35°–90°, SD 14°), and supination 66° (15°–90°, SD 18°) (Table 1). Radiographic parameters at the time of injury were mean volar tilt of −7° (−70° to 35°, SD 26°), radial inclination of 16° (0°–45°, SD 13°), radial height of 9 mm (−14 to 38 mm, SD 12 mm), and ulnar variance of 4 mm (−13 to 28 mm, SD 10 mm). These improved to 7° (0°–15°, SD 5°, $p=0.048$), 26° (18°–31°, SD 5°, $p=0.016$), 16 mm (10–28 mm, SD 5 mm, $p=0.016$), and −2 mm (−8 to 5 mm, SD 3 mm, $p=0.014$), respectively, after original fixation. Calculated p values determine significance from original injury to immediately after ORIF. At final follow-up, the volar tilt was 8° (0°–20°, SD 7°, $p=0.071$), radial inclination 27° (20°–32°, SD 5°, $p=0.097$), radial height 14 mm (4–26 mm,

SD 6 mm, $p=0.019$), and ulnar variance −1 mm (−9 to 6 mm, SD 3 mm, $p=0.006$) with p values representing significance from ORIF to final healing (Table 2).

Complications included four (19 %) nonunions requiring secondary bone grafting and one (5 %) deep infection in an AO closed type C fracture requiring implant removal, antibiotic bead placement, and revision fixation. There were no instances of implant failure, adhesions requiring tenolysis, tendon rupture, or surgeries for implant removal after final fracture healing. One patient (5 %) developed carpal tunnel syndrome after fracture healing requiring release, but no patients developed perioperative carpal tunnel symptoms.

Discussion

Traditionally, fixation of comminuted metadiaphyseal radius fractures has been challenging. Typically, these higher-energy injuries were stabilized with external fixation [8] given either the lack of diaphyseal length of distal plating systems or the inability to adequately control the articular surface with standard systems. However, the definitive treatment of these fractures with external fixators can have high complication rates and can be difficult with obtaining a well-aligned union of the metaphysis to the diaphysis [22].

Weber and Szabo examined 76 patients (15 open fractures) with comminuted fractures of the distal radius [21]. The complication rate with an external fixator alone was 52–63 %. In their study, pin tract infections were the most common, especially with patients in the ICU. Stiffness after fixator removal was also a problem. As the duration of distraction increased, function and motion decreased significantly [9]. Comminuted fractures of the radial metaphysis treated with external fixation and allograft were evaluated in 17 patients [8]. Of these, two had supplemental plates (one dorsal and one volar) and five had supplemental Kirschner wire (K-wire) fixation. Sixteen patients regained at least 75 % of motion, and 12 patients obtained at least 75 % of contralateral grip strength. However, radiographic parameters varied with volar tilt ranging from −5° to

Table 2 Radiographic parameters at injury, after fixation, and at follow-up. All angular measurements are recorded in degrees, and all linear measurements are recorded in millimeters. Volar tilt is defined as (−) when the fracture demonstrated apex volar angulation. Negative ulnar variance is defined as a shorter ulnar length compared to the ulnar side of the radius

Data	Original			After ORIF			Follow-up			Change from original to ORIF		Change from ORIF to final	
		Range	SD		Range	SD		Range	SD		p		p
Volar tilt (°)	−7	−70 to 35	26	7	0–15	5	8	0–20	7	14	0.048*	1	0.070
Radial inclination (°)	16	0–45	13	26	18–31	5	27	20–32	4	10	0.016*	1	0.097
Radial height (mm)	9	−14 to 38	12	16	10–28	5	14	4–26	6	7	0.016*	−2	0.019*
Ulnar variance (mm)	4	−13 to 28	10	−2	−8 to 5	3	−1	−9 to 6	3	−6	0.014*	1	0.006*

SD standard deviation

*$p < 0.05$, statistically significant

6°, radial inclination from 11° to 21°, and radial height from 4 to 9 mm. This study verified that while external fixation can be used as definitive treatment, there is difficulty in restoring consistent radiographic parameters.

Other internal fixation techniques have been reported. Burke and Singer described a case of a comminuted fracture fixed with a 3.5-mm internal bridge plate securing the third metacarpal to the radial shaft, spanning the comminution [1]. This idea was used to treat 22 patients with a bridge or distraction plating technique [6, 18]. With comminuted fractures, the articular surface was pinned in a reduced position in addition to the spanning fixation. The average healing time was 110 days with all patients requiring a secondary procedure for plate removal at an average of 124 days. Complications included an extensor lag of the fingers ranging from 10° to 15° in three patients. Hanel et al. described 62 patients treated with a bridge plate placed in the second compartment [7]. They had similar results with one reported tendon rupture and one broken plate. Mudgal and Ring reported utilizing a T-plate and a DC plate secured together to allow adequate fixation of the distal fragment to the radial shaft [13], and Day et al. described dorsal and volar sandwich plating [3]. While these techniques allow for better bony fixation, bridge plating mandates a second surgery for hardware removal to allow motion. Combined volar and dorsal plating may negatively affect blood flow to the fracture fragments.

Distal radius fracture healing with less than 3 mm of shortening and 10° of dorsal angulation yields more optimal results [2]. Given the high-energy injury necessary to produce metadiaphyseal comminution and resulting displacement of the fracture fragments, ligamentotaxis through external fixation or bridge plating may not restore an acceptable reduction [6, 7, 18, 19]. Open reduction with volar plating systems has been shown to be safe and effective when treating distal radius fractures [15, 17], and the use of external fixation in conjunction can act as a neutralization device postoperatively [10].

Internal fixation also allows the potential for earlier mobilization if secure fixation is obtained. While there is no direct study examining early motion in these fracture patterns, there is evidence that in extra-articular distal radial fractures, early mobilization yields decreased pain, increased grip strength, decreased swelling, and increased functional recovery [4, 5, 11]. Also with intra-articular fractures, if the articular surface can be reduced and secured to the radial shaft, earlier function and improved results can be obtained [16]. Severe metaphyseal comminution or small articular fragments can be concurrently stabilized and maintained with bone graft [20].

Long distally locked volar plates allow reduction and fixation of the articular fragments and metaphyseal fragments to the diaphysis. The metadiaphyseal fracture can be bridged without disrupting the fracture blood supply. Distal locked fixation also stabilizes the reduced distal fragment with maintenance of the volar tilt, radial inclination, radial height, and ulnar variance. With fixation that does not span the radiocarpal joint, the potential for early motion exists without the need for plate removal.

Secondary bone graft surgery was only needed in four (19 %) of patients with three having been bone grafted at the time of original fixation and one having had such a severe injury that required a serratus flap with split thickness skin grafting for coverage. One patient developed carpal tunnel syndrome after a fracture union requiring a carpal tunnel release, but there were no cases of perioperative carpal tunnel syndrome. Only one patient required hardware removal for deep infection, and this occurred in a closed AO type C fracture. It should also be noted that with these higher-energy fractures, we found many associated injuries. A thorough and repeated secondary survey should be conducted with these patients.

The implant that we utilized was able to significantly change and maintain the radiographic alignment of the distal radius with regards to volar tilt, radial inclination, radial

height, and ulnar variance within acceptable parameters for union. There was statistical significance with regards to the change of radial height of 2 mm and ulnar variance of 1 mm from the time of initial fixation to final union. While this may represent some fracture collapse, such small change may also be due to a measuring error and the authors question its clinical significance.

Our study was limited due to its retrospective nature and, as a case series, has no control or comparison group. The injuries were also quite variable and required slightly different fixation in most cases. While every patient underwent volar plating, occasional external fixation was needed. Given our regional referral base, our patient follow-up data are also limited after the treatment of some injuries. Patients are occasionally referred for treatment but obtain follow-up care closer to their home. The retrospective nature of the study also limits the available data to those within the medical record, as evidenced by having flexion and extension data of 15 patients compared to pronation and supination data in 21 patients. The strengths of our study include follow-up of all fractures to radiographic union as well as the large series of patients with this complex fracture pattern.

In summary, fixation of distal radius fractures with metadiaphyseal fracture using a locked long volar plate is a safe and effective procedure for this challenging problem. This method allows direct fixation of both the articular and shaft components without the necessity of a second surgery for hardware removal. The use of adjunctive traditional techniques, such as external fixation, may need to be used in severe articular injuries. Complication rates are low, and less than 20 % of the patients required secondary bone grafting for nonunion.

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