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ORIGINAL ARTICLE

Comparison of Locked Volar Plating Versus Pinning and External Fixation in the Treatment of Unstable Intraarticular Distal Radius Fractures

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Abstract
Introduction We retrospectively compared the outcomes of open reduction and internal fixation (ORIF) with volar locking plate versus standard external fixation and percutaneous pinning in treating similar unstable distal radius fractures with a minimum 2-year follow-up.
Methods The ORIF group included 41 patients with an average follow-up of 29 months. The external fixation group comprised 14 patients with an average follow-up of 33 months. Average age at presentation was 45 years in the external fixation group and 48 years in the ORIF group. The male/female ratios were 16:25 among the ORIF group and 6:8 in the external fixation group. The two groups were compared for clinical and functional outcomes measured by the disabilities of the arm, shoulder, and hand (DASH) score. Pain scores were similar. Radiographic measurements were also evaluated between groups.
Results Final ranges of motion and grip strengths were similar between the two groups. The mean DASH score of the locked volar plate group was 9 compared to 23 for the external fixation group. Radiographically, volar tilt and radial length were significantly better in the patients treated with ORIF. The ORIF group required less therapy visits. No complications occurred in the locked volar plate group whereas two patients had pin tract infections and one had prolonged finger stiffness in the external fixation group.
Conclusion Locked volar plating compares favorably to external fixation and pinning for amenable fracture patterns. Whereas grip and range-of-motion data were similar, DASH scores, frequency of rehabilitation, and some radiographic parameters were superior in patients treated with ORIF.

Keywords Radius fracture · Locked volar plating · External fixation

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Introduction

Distal radius fractures are a serious medical problem. The incidence of these injuries is expected to increase with an aging population. Optimal management of fractures of the distal end of the radius continues to be debated among the orthopedic community. Popular surgical options for unstable distal radius fractures include closed reduction and pin fixation with and without external fixation [5, 7, 15, 16, 20, 24], and open reduction and internal fixation (ORIF) with dorsal-, volar-, and fragment-specific approaches [4, 18, 27, 30, 31, 33]. There are published reports comparing variations and types of pinning/external fixation [5, 13, 15, 20, 35]. Many other investigators have attempted to compare different types of ORIF [31], external fixation, and various types of internal fixation [12, 18, 37].

One of the major challenges in effectively comparing treatments for distal radius fractures lies in the wide variation of injury patterns. In addition, therapeutic algorithms in reference books are often less scientific and more based on author expert opinion. Surgeons may only be comfortable performing one specific operation and then treat all fractures similarly. Difficulty in the interobserver reliability of fracture classification, an unclear definition of instability, and a variety of commonly used scoring systems

pose an impediment to a consensus opinion regarding surgical management of these injuries.

Various studies have reported excellent outcomes with locked volar plating [9, 17, 27–29]. These implants can support both the dorsal and volar subchondral bones from the volar side of the radius. The advantages for this plating system include the ability to hold the intraarticular fragments securely without crossing the wrist. This allows early active wrist motion with preservation of articular alignment. One recent study compared the volar fixed-angle tine plate (Avanta) with external fixation [37]. The purpose of this study is to compare ORIF through a volar approach using a locked volar plate with standard pins and external fixation for the treatment of unstable distal radius fractures.

Materials and Methods

Institutional review board approval was obtained for the study. This investigation was designed to retrospectively evaluate the outcomes of similar distal radius fracture patterns treated by ORIF with locked volar plating versus closed reduction and pinning with external fixation. Patients with unstable distal radius fractures treated by a single surgeon over a 4-year period were reviewed. In an effort to minimize confounding variables, strict attention was paid to comparing similar fracture patterns. The fractures were essentially four parts with a single radial styloid fragment, volar and dorsal lunate fossa fragments, and the diaphysis of the radius. The fractures were deemed operative because of instability. Most patients underwent attempt at closed reduction in the emergency room. In all patients, the distal radius fracture was their lone injury. Based in part on previous studies, characteristics of these unstable fractures included one or more of the following: (1) initial dorsal angulation of greater than 20°, (2) initial shortening greater than 5 mm, (3) greater than 1 mm displaced intraarticular component, (4) radiocarpal intraarticular involvement, (5) associated ulna fracture, (6) significant dorsal cortex comminution, or (7) loss of reduction after closed reduction and immobilization [2, 7, 21, 36]. The fracture patterns were most consistent with a Melone type II classification [26].

This study is based on a change in the practice of the senior author. In the past, many of these fractures were routinely treated with pinning and external fixation (Fig. 1). With the introduction of locking volar plate technology, similar injuries were (and continue to be) treated with ORIF (Fig. 2). The transition in treatment and indications for ORIF evolved during the study period. Most of the patients were treated with external fixation underwent surgery in the earlier portion of the study period, whereas toward the end of the study period, most patients were treated with ORIF. Despite being a retrospective analysis, the authors felt that

Figure 1 **a** and **b** Anteroposterior (AP) and lateral views of a 46-year-old female who sustained a fall. The x-ray demonstrated significantly dorsally angulated and shortened distal radius fracture. **c** and **d** Radiographs at 1 year after surgery demonstrate a healed fracture.

with the identification of similar fracture patterns, we could adequately compare the outcomes of these two treatment options while minimizing confounding variables and bias.

A total of 55 wrists fit the inclusion criteria and were surgically treated between August 2002 and December 2003. Forty-one patients underwent ORIF, and 14 wrists were treated with pinning and external fixation. The pinning and external fixation group included eight females and six males. Their average age was 45 years (range 23–73). The average follow-up among this cohort was 33 months (range 27–36). The ORIF group consisted of 25 females and 16 males. The average age at the time of injury was 48 years (range 22–77). The dominant extremity was affected in 30 patients. The overall average follow-up was 29 months (range 25–34). The two groups were compared for pain, range-of-motion (ROM), strength, satisfaction, and functional outcome measured by the disabilities of the arm, shoulder, and hand (DASH) score. The radiographic data was measured with a goniometer and included evaluation of radial length, inclination, and tilt. Healing was defined both clinically (no pain at the fracture site) and radiographically (consolidation of the fracture). The number of therapy visits required after

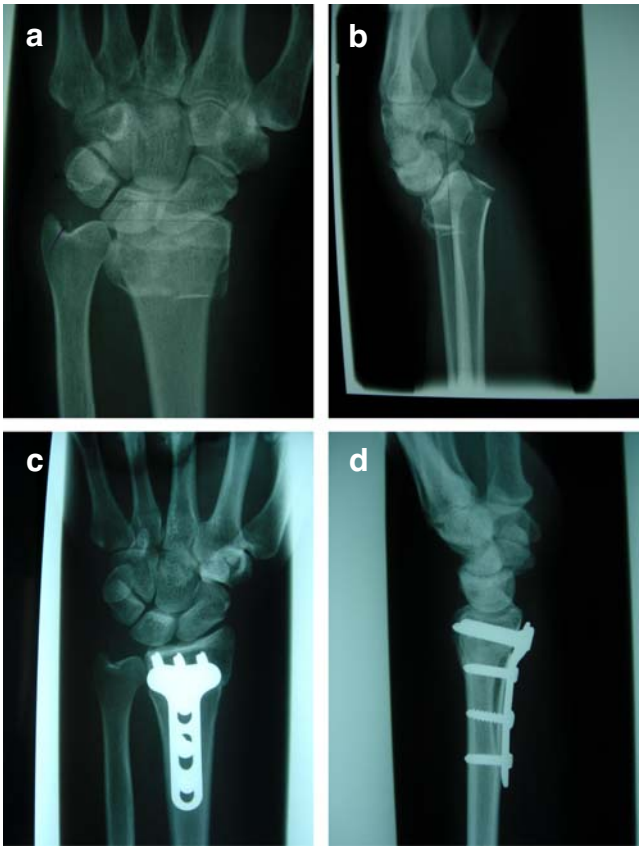

Figure 2 **a** and **b** AP and lateral radiographs demonstrating a similar type of fracture as shown in Fig 1. **b** and **c** Postoperative films after locked volar plate show a well-maintained reduction with stable fixation.

the initialization of ROM were also measured and compared between groups. The patients were followed-up at consistent intervals until healed. Typically, this consisted of 2, 4, 6, and 10 weeks, 6 months, and yearly intervals. No patients were lost in follow-up. Table 1 contains a summary of the demographic data between the two groups. Statistical analysis was performed using Student's *t* test and significance was determined at $P<0.05$.

Pinning and External Fixation Technique

The fracture is reduced with traction and direct manipulation. A series of k-wires are then used to maintain the reduction. Typically, at least three 0.62 k-wires are used to secure the radial styloid to the diaphysis. This is followed by two 0.45 subchondral k-wires from the radial styloid to the lunate facet fragments. On occasion, dorsal-to-volar Kapandji-style pins are utilized to help maintain the reduction. After k-wire stabilization, the external fixator is applied. Two pins are placed into the index finger metacarpal through a dorsal–radial incision. The apparatus is measured out to length and an incision is placed over the radial–dorsal aspect of the radius. Two radius pins are placed between the extensor carpi radialis brevis and longus. The device is then secured and the traction is removed. Final x-rays are used to confirm that the reduction is maintained. A bulky dressing and splint is applied.

Postoperatively, the fixator remains in place for approximately 6 weeks. Finger ROM is encouraged immediately. At 2 weeks after surgery, the sutures are removed and x-rays obtained. A supportive removable splint is prescribed and pin care initiated. Wrist ROM is started after external fixator removal. Strengthening is initiated as ROM improves and symptoms normalize.

Open Reduction and Internal Fixation Technique

The volar-modified Henry approach is performed between the flexor carpi radialis and radial artery. The pronator quadratus is sharply taken off the radial aspect of the radius and reflected ulnarly to facilitate exposure of the fracture. Under direct visualization and the aid of fluoroscopy, the fracture is then reduced. Depending on the difficulty in achieving the reduction, provisional fixation with k-wires can be occasionally utilized. The plate and screws are placed and the provisional fixation (in use) is removed. The plate is initially secured proximally with a 3.5-mm cortical screw. Upon confirming adequate placement of the plate, a second screw proximal to the fracture is used to firmly secure the hardware. Distal fixation with locking screws is then performed while maintaining the fracture reduced. The remaining proximal fixation is then completed. In a few cases, k-wires in the radial styloid were temporarily maintained and buried beneath the skin for 4 weeks.

Postoperatively, the patient is immobilized for 10–14 days. The patient is then graduated to a removable splint and gentle ROM is initiated. Over the next 2–4 weeks, progressive advancement of motion is performed. Depending on the clinical and radiographic exam, activity is advanced to include strengthening at approximately 6 weeks. Provided that recovery proceeds in the expected fashion, follow-up appointments occur at 10 weeks, 6 months, and 1 year post injury.

Table 1 Demographic data between groups.

	Volar Plate Group (N=41)	Ex-fix and Pinning (N=14)
Gender (M/F ratio)	16:25	6:8
Average age (years)	48 (22–77)	45 (23–73)
Average follow-up (months)	29 (25–34)	33 (27–36)

Results

The clinical and radiographic data are summarized for both groups in Tables 2 and 3. The final ranges of motion and grip strengths were similar between the two groups. Wrist flexion and extension measured 64° and 69° in the ORIF group versus 59° and 63°, respectively, in the external fixation cohort. Radial and ulnar deviation averaged 23 and 34, respectively, in the ORIF group, and 21 and 31, respectively, in the ex-fix and pinning group. Pronation and supination were also not significantly different; the ORIF group measured 78/76° versus 73/72° with the external fixation and pinning group. The grip strengths measured 26 kg (88% contralateral) in the ORIF group and 29 kg (90% contralateral) in the external fixation and pinning group. Pain scores (on visual analog scale of 0–10) were not significantly different between groups with an average score of 1.7 for the ORIF group and 2.1 in the external fixation group. The mean DASH score of the locked volar plate group was 9 compared to 23 for the external fixation group (P=0.015). Clinical healing was defined by the absence of pain at the fracture site to direct pressure. In the external fixation group, it was 5.8 weeks, and in the ORIF group, it was 5.5 weeks.

For radiographic analysis, the ulnar variance (radial length), articular step-off, and volar tilt all showed statistically significant outcomes favoring the locked volar plate group. The mean ulnar variance was −0.3 mm (range −2–0) for the ORIF group versus +1.3 mm (range 0.3–3) for the ex-fix group (P=0.013). The articular step-off was 0.2 mm (range 0–1) for the ORIF group versus 0.8 mm (range 0–2) for the ex-fix group. The volar tilt averaged 11° (range 3–20) for the ORIF group versus 5° (range −3–12) for the ex-fix group (P=0.041). Radial height and inclination were not significantly different between groups. In the ORIF group, the radial height measured 11 mm (range 7–13); whereas in the external fixation group it averaged 10 mm (range 6–12). The radial inclination measured 23° (range 18–27) and 21° (15–25) between the ORIF and external fixation cohorts, respectively.

There was a significant difference in the number of hand therapy visits required between groups in favor of the ORIF patients. On average, the volar plate group required four therapy appointments versus an average of ten in the external fixation group (P=0.01). No complications occurred in the locked volar plate group, whereas two patients had a pin tract infection and one had prolonged finger stiffness in the external fixation group.

Table 2 Clinical outcome data at final follow-up.

	Volar Plate Group (N=41)	Ex-fix/Pinning Group (N=14)	P Value
Pain (0–10)	1.7 (0–5)	2.1 (0–5)	NS
Flexion (°)	64 (46–88)	59 (40–85)	NS
Extension (°)	69 (40–90)	63 (36–80)	NS
Radial deviation (°)	23 (15–28)	21 (12–25)	NS
Ulnar deviation (°)	34 (22–40)	31 (20–40)	NS
Pronation (°)	78 (60–80)	73 (55–80)	NS
Supination (°)	76 (58–80)	72 (57–80)	NS
Grip strength, kg (% contralateral)	26 (88)	29 (90)	NS
Time to clinical healing (weeks)	5.5 (3–7)	5.8 (4–7)	NS
DASH score	9 (0–23)	23 (0–65)	0.015
Therapy sessions	4 (1–10)	10 (4–20)	0.01
Complications	None	Pin tract infection (2), finger stiffness (1)	

Table 3 Radiographic results at final follow-up to date.

	Volar Plate Group (N=41)	Ex-fix/Pinning Group (N=14)	P Value
Ulnar variance (mm)	−0.3 (−2–0)	+1.3 (−0.3–3)	0.013
Articular step-off (mm)	0.2 (0–1)	0.8 (0–2)	NS
Volar tilt (°)	11 (3–20)	3 (−3–12)	0.041
Radial height (mm)	11 (7–13)	10 (6–12)	NS
Radial inclination (°)	23 (18–27)	21 (15–25)	NS

Discussion

The use of external fixation and pinning has demonstrated successful outcomes in multiple studies [7, 10, 16, 18, 23]. Cooney et al. demonstrated 90% good and excellent results in their review of external fixation and pinning for unstable distal radius fractures [7]. Superiority to closed reduction and casting has been demonstrated in several studies [1, 5, 14, 34]. In the current study, the clinical outcomes and radiographic parameters in patients treated with external fixation are comparable. In our practice, this technique maintains an important role in the treatment of distal radius fractures.

Several prospective studies have included external fixation and various methods of fixation [15, 24, 25]. Hutchinson et al. prospectively evaluated external fixation and pins with plaster techniques [15]. Clinical outcomes were similar between groups. The external fixation group was better at maintaining radial length long-term. However, it was more costly and sustained a greater number of minor complications including radial neuritis and pin tract infections. McQueen et al. prospectively evaluated four options in the treatment of distal radius fractures that had lost their reduction after attempted closed treatment: (1) remanipulation and plaster, (2) open reduction and bone grafting, (3) closed reduction and application of external fixator (3) with mobilization at 3 weeks, and (4) without mobilization at 3 weeks [25]. Despite improved radiographic appearance in the open

reduction and bone grafting group, clinical outcomes were similar between groups at 1 year follow-up. Evaluation of studies directly comparing ORIF and external fixation and pinning are mentioned later in the discussion.

Complications with external fixation have occurred and in some reports can be common [3, 15]. One study has reported that displacement can occur up to 6 months after fracture [8]. Another paper noted 16 of 24 patients treated with external fixation had complications ranging from infection to superficial nerve neuropraxias [3]. Problems encountered included: pin tract infections (9 patients), median and radial neuropathies (5 patients), and loss of reduction (4 patients). Hutchinson et al. also noted a 45% complication rate of which half were considered serious or major [15]. The most common problems again included pin tract infections, radial neuritis, and complex regional pain syndrome. We encountered one case of finger stiffness and two cases of superficial pin tract infections in the current series.

Volar locking plates have gained popularity over the last several years. The potential advantages of the volar fixed-angle implants include a decreased rate of complications when compared with dorsal plating or external fixation, subchondral support through the fixed-angle tines, and initiation of early wrist motion exercises [6, 9, 22, 27–29, 32]. Orbay and Fernandez reported results of ORIF with locking volar plates at 12 months follow-up on 31 distal radius fractures and found excellent ROM with flexion/extension of 57/59° and radial/ulnar deviation of 17/27°, respectively [28]. Overall grip strength measured 79% of the contralateral side. The overall outcome according to the Gartland and Werley scales showed 19 excellent and 12 good results. Many other investigators using alternate plating systems mirror these results [6, 17, 27]. The results of ORIF in the current study are similar to previously reported outcomes. Good clinical, patient-related, and radiographic measures were obtained. In addition, no complications to date have been observed in patients treated with ORIF.

Because of the strength and stability of the construct, the use of locked plates allows early wrist motion and this has been shown to enhance hand and finger functions [11]. However, early motion may only provide a theoretical benefit as shown by the study of Krishnan et al. [20]. Their study compared a nonbridging external fixator with a bridging external fixator system for the treatment of comminuted intraarticular fractures of the distal radius in a prospective randomized control trial. The results did not demonstrate a statistically significant difference in the radiological and clinical outcomes achieved with these two treatments. Our study similarly did not demonstrate a significant difference in ROM between groups despite the fact that the ORIF population started wrist motion much sooner than the external fixation patients. However, it was observed that patients were quite pleased to initiate early ROM.

There are few studies directly comparing ORIF and external fixation with pinning [18, 19, 37, 38]. And even fewer studies specifically comparing locked volar plates and external fixation [37]. Kreder et al. published a prospective multicenter evaluation comparing various types of ORIF with indirect reduction and percutaneous fixation [19]. They compared 88 in the external fixation group and 91 in the ORIF group. The ORIF group consisted of both volar and dorsal plating. They concluded that the indirect reduction group had a more rapid return to function and better overall outcome than the ORIF group. This is contrary to our results. However, the ORIF patients in their study included all types of fixation systems and not simply volar plating.

Wright et al. compared the results of unstable distal fractures treated with external fixation or a fixed-angle volar plate [37]. The authors found that the patient-rated wrist evaluation and DASH scores for the groups were statistically equivalent. Intraarticular step-off, volar tilt, radial length, and ulnar variance were better in the ORIF group, yet failed to reach statistical significance. Overall ROM parameters were similar between groups. The external fixation group had improved grip strength, which was ascribed to the fact that they had longer-term follow-up. An additional study, not in the English literature, reviewed 26 patients comparing external fixation to volar locking plates in the treatment of distal radius fractures [38]. The anatomical results favored the open reduction internal fixation group. Functional results at both 6 months and 1 year showed no differences between these two types of fixation. The complication rate was higher in external fixation group.

The results of our study are similar with regard to pain scores, ROM, and grip strength. The patients who underwent ORIF had improved DASH scores. Despite this, there was no difference in pain scores between groups. Given the similar objective outcomes between groups, there is no obvious explanation for the discrepancy in DASH scores. It may in part be related to their general satisfaction with their postoperative regimen compared to the external fixation cohort. Closer examination of the DASH scores showed that the greatest differences lied not in patients' ability to perform specific tasks; rather, the discrepancies were more evident in questions related to problems/difficulties whereby their extremity affected their work, activities of daily living, and sleep. A possible explanation for the ORIF cohort's satisfaction could be that the patients' impression might have also been inadvertently biased by the surgeon. The senior author informed patients of this "new" method of fixation and the enthusiasm for it may have been contagious. A prospective blinded evaluation would help validate a DASH score (or any other patient functional outcome).

This study examined the differences in the number of hand therapy appointments postoperatively, and we did notice a significant difference between groups. After careful

review of this data, reasons for this discrepancy seem most likely secondary to the therapy protocol as it applies to the external fixator group. Whereas the fixator remained in place, visits were made to ensure fabrication of a supportive splint, finger ROM was satisfactory and progressing, and appropriate pin care was maintained. Some would argue that these might be excessive and unnecessary. After fixator removal, new splints and therapy for wrist motion were initiated. In addition, there was one patient with prolonged stiffness who required a significant number (20) of visits, which contributed to the discrepancy. In fact, the lone patient with only four visits in the external fixator group was noncompliant and missed multiple appointments. An additional confounding variable includes the fact that multiple therapists were involved in the overall patient care. A better and more valid assessment of differences could be performed by a consistent rehabilitation protocol between groups, a more balanced number between cohorts, use of a single therapist, and a prospective analysis.

Shortcomings of our study are mostly because of the retrospective nature of the study. In addition, despite our best efforts to identify similar fracture patterns for treatment, there was some inevitable variability. The numbers of patients were not well balanced and there were moderately fewer patients in the external fixation group. Preoperative and postoperative outcome measures would have added to the validity of the DASH scores and discrepancies that were noted. A controlled prospective randomized trial specifically comparing these two treatments would better determine the differences in patient outcomes. In our institution, stable fractures are treated nonoperatively. All other fractures could be included in a prospective trial. Eventually, large numbers of patients would be needed to break down results by specific fracture type.

Whereas external fixation maintains a significant role in the treatment of distal radius fractures, ORIF with locked volar plating has changed the way many surgeons treat certain types of distal radius fractures. The aim of this study was to compare the results of external fixation and ORIF in treating similar distal radius fracture patterns. Whereas grip and ROM data were similar between groups, DASH scores, frequency of hand therapy visits, and some radiographic parameters were superior in patients treated with ORIF. These results suggest that locked volar plating is an appropriate treatment for these distal radius fracture patterns.

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