SCIENTIFIC ARTICLE

Prospective Evaluation of Distal Radius Fractures Treated With Variable-Angle Volar Locking Plates

John R. Fowler, MD, Asif M. Ilyas, MD

Purpose To evaluate the radiographic, objective (range of motion and grip strength), and subjective outcomes of variable-angle volar locking plate (VAVLP) fixation for unstable distal radius fractures.

Methods Over a 12-month period, we prospectively evaluated 39 consecutive distal radius fractures treated operatively with VAVLPs. Surgical exposure, fracture reduction, plate application, and postoperative rehabilitation were uniformly performed. Clinical outcome and radiographic measures, with a minimum follow-up of 12 months, were obtained.

Results Final follow-up data were available in 37 patients (26 females and 11 males) with average age of 57 years (range, 16−89 y). The average follow-up time was 14 months (range, 12−22 mo). At final evaluation, average volar tilt was 3°, average radial inclination was 21°, average radial height was 12 mm, and average ulnar variance was −0.2 mm. There was no statistical difference between first postoperative and 1-year follow-up radiographs for any of the measured variables, although there were 4 cases of loss of volar tilt. Average Disabilities of the Arm, Shoulder, and Hand score was 6 and average visual analog scale pain score was 0.3. Mean grip strength at 1 year was 96% of the contralateral side. There was 1 case of variable-angle locking screw loosening and 1 case of extensor tenosynovitis requiring hardware removal. There were no tendon ruptures.

Conclusions The VAVLP fixation restored and maintained acceptable reduction in all patients in this series with a complication rate comparable to standard volar fixed-angle locking plates. Treatment of unstable distal radius fractures with a VAVLP resulted in excellent clinical outcomes at 1-year follow-up. However, use of the VAVLP risks soft tissue irritation, hardware failure, and loss of fracture reduction. *(J Hand Surg 2013;38A:2198−2203. Copyright © 2013 by the American Society for Surgery of the Hand. All rights reserved.)*

Type of study/level of evidence Therapeutic IV.

Key words Distal radius, volar locking plate, variable angle.

From the Department of Orthopaedics, University of Pittsburgh, Pittsburgh; and the Rothman Institute, Thomas Jefferson University, Philadelphia, PA.

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Corresponding author: John R. Fowler, MD, Department of Orthopaedics, University of Pittsburgh, 3471 Fifth Ave., Suite 1010, Pittsburgh, PA 15213; e-mail: johnfowler10@gmail.com.

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DISTAL RADIUS FRACTURES ARE among the most common fractures treated,[1] accounting for 10% to 25% of all fractures.[2,3] Greater than 10% of Caucasian women will experience a distal radius fracture in their lifetime.[4] The overall number of these fractures is expected to increase over 50% by the year 2030.[5] The burden of these fractures in the United States alone is high, with 640,000 distal radius fractures occurring per year.[6] Many of these fractures are adequately treated nonoperatively. However, it is estimated that 40% to 49% are unstable and may benefit from operative treatment.[7,8]

Volar plate fixation has emerged as a popular method of treatment for internal fixation of unstable distal radius fractures.[9–17] This popularity is partly the result of the biomechanical advantages of volar plate fixation compared with other methods.[14,18–21] Numerous studies have confirmed the importance of restoring and maintaining anatomic alignment for optimal functional outcome[22–26] and prevention of residual articular incongruence, which is associated with the development of posttraumatic arthritis.[26,27] Volar locking plate fixation has been demonstrated to allow restoration of radiographic parameters within accepted standards.[2,5,10–12,14,16,17,21,28,29]

Variable-angle volar locking plates (VAVLPs) have increased versatility in subchondral screw placement while maintaining the advantages of a standard fixed-angle locking plates.[5,13] In particular, VAVLPs facilitate surgeon-directed targeted placement of the subchondral screws that can potentially maximize fracture fragment fixation. However, functional and radiographic outcomes have been sparsely reported in the literature.[5,13] The purpose of this study was to evaluate the radiographic, objective (range of motion and grip strength), and subjective outcomes of VAVLP fixation for unstable distal radius fractures.

MATERIALS AND METHODS

From January 2011 to December 2011, we prospectively evaluated all consecutive distal radius fractures requiring operative management treated with a VAVLP, after obtaining approval from our institutional review board. All fractures were treated with the Aptus Distal Radius 2.5 plate (Medartis, Kennett Square, PA) (Fig. 1). Inclusion criteria included patient age of 18 to 89 years, a displaced and/or unstable distal radius fracture requiring open reduction internal fixation, and a minimum final clinical and radiographic follow-up of 12 months.

A displaced distal radius fracture was defined as a fracture with any of the following criteria: greater than 20° dorsal angulation,[24] less than 5 mm radial height, less than 10° radial inclination, greater than 2 mm positive ulnar variance, and greater than 1 mm articular incongruity.

Acceptable closed reduction of a distal radius fracture was defined as less than 10° dorsal angulation,[24] greater than 5 mm radial height, greater than 15° radial inclination,[24] less than 1 mm positive ulnar variance, and 1 mm or less articular incongruity.

An unstable distal radius fracture was defined as possessing variables that, if present, would result in the fracture re-displacing into an unacceptable alignment even if a successful closed reduction were obtained. Variables of instability included any of the following criteria: dorsal comminution greater than 50% of the width of the dorsal cortex or any volar cortical comminution, initial dorsal angulation greater than 20°, initial fracture displacement or translation greater than 1 cm, intra-articular disruption, and an associated ulnar neck or shaft fracture. Surgery was recommended to patients whose fractures could not be reduced successfully by closed means or whose fractures were displaced and had associated variables of instability.

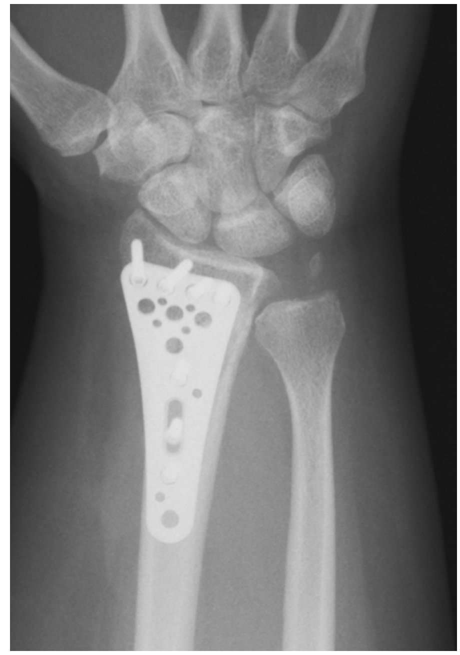

FIGURE 1: Anteroposterior radiograph of the Medartis Aptus 2.5 Radius plate.

The senior author (A.M.I.) classified fractures as A, B, or C, based on the AO classification system.[30] Radial height, inclination, volar tilt, and ulnar variance of the operative side were measured at the first postoperative and 1-year follow-up visits by a fellowship-trained orthopedic hand surgeon who was blinded to the study protocol.

We obtained data on wrist extension, flexion, radial and ulnar deviation, forearm supination and pronation, grip strength (measured as a percentage of the contralateral uninjured side), Disabilities of the Arm, Shoulder, and Hand scores, and visual analog scale scores at 6 weeks and 3 and 12 months postoperatively. An athletic trainer who was blinded to the study protocol measured range of motion and grip strength. Fracture union was defined as the presence of bridging bone on orthogonal views.

TABLE 1. Average Values at Specific Follow-Up Visits

	2 wk	6 wk	12 wk	52 wk
DASH	50	26	16	6
VAS	3.1	2.0	1.3	0.3
Wrist extension (°)	29	55	72	82
Wrist flexion (°)	36	52	72	82
Forearm supination (°)	60	75	85	87
Forearm pronation (°)	76	80	85	84
Radial deviation (°)	9	13	19	19
Ulnar deviation (°)	16	26	35	36
Grip strength (% contralateral)	25	53	77	96

DASH, Disabilities of the Arm, Shoulder, and Hand; VAS, visual analog scale.

Implant

The Medartis Aptus Distal Radius 2.5 is a titanium anatomically shaped volar locking plate with multidirectional distal locking holes that allow up to 15° angulation in all directions while maintaining an ability for screws to lock into the plate. The plate accepts 2.5-mm locking or cortical screws in all holes. In contrast to other systems in which the locking screw cuts into the plate to achieve fixed-angle configuration, the locking technology used in this plate system is based on a 3-point wedging friction lock.

Surgical technique

The senior author (A.M.I.), a fellowship-trained orthopedic hand surgeon, performed all surgical procedures. Either regional or general anesthesia was used in all cases with tourniquet control. The volar distal radius was exposed through a medially reflected flexor carpi radialis approach.[31] As a matter of surgeon preference, to aid in exposure and fracture reduction, the brachioradialis was released in all cases. The first dorsal compartment was not released in any case. The pronator quadratus was released along the radial border and elevated in a subperiosteal fashion. All fractures were reduced and internally stabilized with a VAVLP. Although nonlocking screws were often used to target and reduce fragments to the plate, all distal row screws were routinely replaced and/or filled with only variable-angle locking screws. The variable-angle functionality of the plate was routinely used to obtain subchondral screw placement in the distal row, although we were unable to objectively quantify the angle for each screw and distance to subchondral bone compared with fixed-angle screws. No fixed-angle subchondral locking screws were placed in any cases. The length of the distal subchondral screws was preferentially placed 1 to 2 mm less than the measured length. However, the shaft screws were all placed bicortically. We closed the subcutaneous tissue and skin in layers and applied a bulky soft short arm dressing.

Postoperative management

Immediately after surgery, the patient was encouraged to keep the hand elevated and initiate early and unrestricted finger motion. The postoperative soft dressing was left in place for 10 to 14 days until the first office visit. At that visit, sutures were removed, radiographs were taken, and therapy was initiated under the supervision of an occupational certified hand therapist. From weeks 2 to 6, aggressive anti-edema, tendon gliding, and range of motion exercises were continued. A protective orthosis was provided to be used as needed. After 6 weeks, the patient was reevaluated and advanced to progressive strengthening and resistance exercises. In addition, orthosis use was formally discontinued. At 12 weeks postoperatively, the patient was reevaluated and advanced to a work-hardening program or discharged from therapy, depending on occupational needs. A final postoperative visit was performed at 12 months postoperatively.

RESULTS

Final follow-up data were available in 37 patients (95%) (26 females and 11 males) with average age of 57 years (range, 16–89 y). Two patients were lost to follow-up and did not complete the 12-month examination or radiographs. The average follow-up time was 14 months (range, 12–22 mo). The AO fracture classification included 5 type A, 2 type B, and 30 type C fractures. A total of 21 fractures (57%) affected the dominant hand and 22 fractures (59%) affected the right hand. The Disabilities of the Arm, Shoulder, and Hand and visual analog scale pain scores improved at each follow-up visit (Table 1). Range of motion and grip strength were also improved at 1 year.

Radiographic evaluation confirmed fracture healing in all patients by 3 months. Table 2 compares average volar tilt, radial inclination, radial height, and ulnar variance at the first postoperative visit and at 12-month follow-up. One patient experienced a 10° loss of volar tilt and 4 patients experienced loss of volar tilt between 5° and 10°. There were no statistical

TABLE 2. Radiographic Parameters at First Postoperative Visit and 1-Year Follow-Up Visit

Parameter	First Postoperative Average	12-Month Average	*P*
Volar tilt (°)	3 ± 5	2 ± 6	.7
Radial inclination (°)	20 ± 6	21 ± 5	.4
Radial height, mm	11 ± 4	12 ± 3	.5
Ulnar variance, mm	0 ± 1	0 ± 1	.8

FIGURE 2: Lateral radiograph of a patient who underwent screw removal for extensor tenosynovitis, demonstrating the prominent screw in the distal row.

differences between the first postoperative visit and final follow-up radiographs for any measured variables. Given the previously mentioned acceptable criteria for reduction (< 10° dorsal angulation, > 5 mm radial height, > 15° radial inclination, and < 1 mm positive ulnar variance), 100% of patients maintained acceptable alignment at final follow-up. However, we noted an 11% incidence (4 of 37 cases) of loss of reduction from immediately postoperative to final postoperative radiographic evaluation.

Complications included 1 case of extensor tenosynovitis from prominent dorsal screw penetration and 1 case of loosening and backing out of subchondral variable-angle locking screws. The first case (Fig. 2) had an AO type B3 pattern that required removal of hardware with extensor tenosynovectomy at 6 months postoperatively. The second case (Fig. 3) had an AO type C3 fracture pattern that was otherwise asymptomatic and did not require additional surgery at final follow-up. We noted no other cases of change in the position of variable-angle locking screws from initial to the final follow-up radiographs.

FIGURE 3: Lateral radiograph showing 1 of the distal locking screws not fully engaged into the plate.

DISCUSSION

Volar plate fixation with fixed-angle locking screws for the operative treatment of unstable distal radius fractures has generally produced acceptable outcomes with respect to both functional and radiographic parameters.[10,11,13,16,17,29,32] Certain studies have found loss of reduction at short-term follow-up using fixed-angle volar plates.[11,16,17,29] One series showed that up to 40% of patients lost more than 5° volar tilt.[11] The use of variable-angle locking screws has been proposed to allow increased flexibility in plate positioning and subchondral screw placement, possibly improving fracture purchase and maintenance of reduction. The purpose of this study was to prospectively evaluate functional and radiographic outcomes using VAVLP fixation. Our experience with VAVLP confirms maintenance of radiographic reduction at final follow-up with excellent clinical outcomes, which we believe resulted at least in part from the variable-angle component of VAVLP. However, a poorly reduced fracture or unfamiliarity with the articular anatomy of the distal radius leaves VAVLP fixation vulnerable to errant screw placement. In addition, VAVLP is not without risks of complication, including soft tissue irritation, hardware failure, and loss of fracture reduction.

The VAVLP was able to maintain acceptable radiographic reduction with a complication rate comparable to standard fixed-angle volar plate fixation. Although radiographic measurements are vulnerable to measurement bias and quality of positioning and imaging, our independent observer found negligible differences between the first and last follow-up visits in 89% of cases. However, there were 4 cases with loss of reduction at final follow-up.

We assume that the 2 hardware complications in this series resulted from surgeon error. The case requiring removal of hardware was directly due to prominent dorsal screw penetration. Screw tip prominence dorsally has been well established to result in extensor tendon irritation.[33] Similarly, the case involving backing out of the subchondral locking screws likely resulted from either inadequate locking of the screw to the plate or placement of the screw outside the 15° arc of angulation that the manufacturer prescribes. In the latter case, the hardware had not resulted in loss of fracture reduction or flexor tendon irritation at last follow-up.

Figl et al[5] retrospectively reviewed 85 patients who underwent variable-angle volar plate fixation (Aptus plate; Medartis AG, Basel Switzerland) for unstable distal radius fractures and found that radial height was maintained in 75% of patients at 1-year follow-up and that no patients had lost acceptable reduction. The current study echoes these results. Patients in the series of Figl et al obtained an average wrist extension of 54° and wrist flexion of 52°. Patients in our series achieved better flexion and extension at 80° and 81°, respectively. Figl et al found forearm pronation and supination to average 86° and 87°, respectively. Patients in the current series achieved comparable motion. The series of Figl et al was retrospective in nature and included a much lower proportion of AO type C fractures, 34 of 80 (43%), compared with our prospective study, which had 30 of 37 AO type C fractures (81%).

Mignemi et al[13] performed a retrospective review of 185 distal radius fractures that underwent fixed-angle volar plate fixation (Hand Innovations DVR plate; DePuy, Warsaw, IN). That retrospective series introduced considerable potential for bias by excluding 130 of 420 potential fractures (31%) because of a lack of adequate radiographs or a lack of follow-up. In addition, 48 of 185 patients (26%) had no injury radiographs and therefore were not included in the analysis based on fracture type. The authors found that 88% of patients in their series achieved acceptable radiographic parameters after internal fixation, defined as less than 20° dorsal tilt, greater than 10° radial inclination, and less than 5 mm ulnar variance. These parameters remained stable from radiographs taken in the immediate postoperative period compared with final follow-up at 3 months. Despite a higher average age, 57 years in the current study compared with 49 years in the study of Mignemi et al, and a higher percentage of AO type C fractures, 30 of 37 in the current study (81%) compared with 91 of 137 in the study of Mignemi et al (67%), the current study found 100% acceptable radiographic parameters using the same criteria.

Strengths of this study include the high follow-up rate (95%), standardized protocol by a single surgeon, and a prospective design with a minimum 12-month follow-up. The prospective nature of this study provides a high level of evidence for the use of this implant and confirms the findings of previous retrospective studies regarding the use VAVLP.[5] The current study also demonstrated that VAVLP can be successfully used in AO type C fractures. Moreover, we routinely use VAVLP for all of our distal radius fractures, so there was no selection bias in terms of choosing a fixed-angle versus a variable angle construct in this study. Limitations include the use of a single type of VAVLP, in that outcomes may not be transferable to other plates. Future studies could benefit from a comparative study with a fixed-angle volar locking plate construct.

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