Arch Trauma Res. 2016 June; 5(2):e25174. doi: 10.5812/atr.25174.

Published online 2016 May 9. **Research Article**

Surgical Treatment of Unstable Distal Radius Fractures With a Volar Variable-Angle Locking Plate: Clinical and Radiological Outcomes

Kavin Khatri,[1,*] Vijay Sharma,[2] Kamran Farooque,[2] and Vivek Tiwari[2]

[1]Department of Orthopaedics, GGS Medical College Faridkot, Baba Farid University of Health Sciences, Faridkot, India
[2]Department of Orthopaedics, Jai Prakash Narayan Apex Trauma Centre, All India Institute of Medical Sciences, (AIIMS), New Delhi, Delhi, India

[*]*Corresponding author*: Kavin Khatri, Department of Orthopaedics, GGS Medical College Faridkot, Baba Farid University of Health Sciences, Faridkot, India. Tel: +91-8743878077, E-mail: kavinkhatri84@gmail.com

Received 2014 November 07; **Revised** 2015 April 13; **Accepted** 2015 November 30.

Abstract

Background: Unstable distal end radius fractures are difficult to manage and so various treatment modalities have been described. The use of variable-angle locking plates is promoted for the management of these fractures.
Objectives: This study aimed to evaluate the functional and radiological outcomes in unstable distal end radius fractures treated with variable-angle locking plates.
Patients and Methods: We reviewed 23 unstable distal end radius fractures that were treated at our institution with volar variable-angle locking plates. The mean age of the patients was 32.82 $\pm$ 11.81 years (range 19 to 62) and the mean duration of follow-up was 11.04 $\pm$ 2.47 months (range 6 to 15). All of the patients underwent open reduction and internal fixation with a variable-angle locking plate. Radiological parameters such as radial inclination, length, tilt, and ulnar variance were measured at six weeks and at the final follow-up. The functional evaluation was conducted by measuring the range of motion at the wrist joint as well as the grip strength. Gartland and Werley's demerit scoring system was used to assess the final outcome.
Results: There were two cases of superficial infection that responded to oral antibiotics. One patient had developed a hypertrophic scar, while another had carpal tunnel syndrome that was conservatively managed. There was a significant improvement in the functional indices from six weeks to the final follow-up, while the radiological parameters were maintained. According to Gartland and Werley, excellent results were reported in 65.2% cases, while good results were present in 35% cases.
Conclusions: The use of variable-angle locking plates in treating unstable distal end radius fractures is associated with excellent to good functional outcomes with minimal complications.

Keywords: Bone Plates, Radius, Volar Plate, Fracture Fixation, Internal, Injury, Wrist

1. Background

Distal end radius fractures constitutes 10% of all human skeletal fractures (1). Such fractures mainly affect the elderly population and they involve low energy trauma (2). However, in young adults, high energy trauma such as that resulting from vehicular traffic accidents accounts for a substantial number of cases, the majority of which are unstable.

Restoration of volar angulation, radial length, and radial inclination are essential for good functional outcomes at the wrist joint. Maintenance of articular congruity and stable fixation reduce the incidence of osteoarthritis and also help with earlier rehabilitation (3). Various treatment modalities, including plaster cast application, Kirschner wire fixation, dorsal and volar plates, and external fixation, have been described for the management of these fractures (4, 5). Osteoporosis is one of the major factors in deciding on the treatment modality (6), and locking plates are favored in the treatment of these complex fractures.

Locking volar plates mechanically bridge the bone and bear the load through the locking construct, resulting in a lower incidence of failure. The subchondral placement of distal screws is essential to prevent a loss of correction and to achieve good functional results (5). Comminuted distal end radius fractures may require the use of additional fixation methods such as Kirschner wire and dorsal plate in addition to volar fixed-angle plates. This is because the volar fixed-angle locking plates allow the screws to be inserted in a predefined direction, and they do not take into account the personality of the fracture and any variability in the positioning of the plate. This type of fracture can be better managed with the use of a variable-angle plate as it allows greater flexibility in terms of screw angle insertion and the engagement of periarticular fragments (7).

There have been a number of studies on the operative management of distal end radius fractures treated with fixed-angle volar locking plates; however, the literature on the functional and radiological outcomes in those treated

with variable-angle locking plates (VALP) is scarce.

2. Objectives

We retrospectively analyzed the results in a selected cohort of patients with unstable distal end radius fractures in order to determine the functional and radiological outcomes of treatment with VALP.

3. Patients and Methods

We performed a retrospective review of patients with distal end radius fractures who were treated operatively between June 2013 and March 2014 and then followed up for at least six months. The inclusion criteria for the study were as follows:

1. Patients aged between 18 to 70 years with isolated closed intra-articular distal end radius fractures displaced more than 2 mm from the anatomic position, a dorsal inclination of the distal fragment of more than 20°, a radial shortening of 10 mm or more, and dorsal comminution (8-10).

2. No previous history of ipsilateral elbow and shoulder by means of fracture, inflammation or osteoarthritis.

3. Absence of major medical comorbidities (i.e., uncontrolled hypertension, previous myocardial infarction, stroke, morbid obesity, or uncontrolled diabetes mellitus).

The exclusion criteria for the study were:

1. Pathological fracture.

2. Patients with delayed presentation (> two weeks).

3. Bilateral wrist fractures.

4. Associated injuries that increase the risk of surgery or prevent compliance with subsequent rehabilitation protocols (i.e., severe head injuries, spinal cord injury).

5. Pregnant females.

All of the preoperative (Figure 1) and postoperative data were obtained by reviewing the charts from the medical records section of the institution. The patients were contacted by telephone or letter to arrange an additional visit. All of the patients gave informed consent to participate in the study. The study was approved by the institutional review board.

A total of 23 patients were willing to participate in this study. The other 15 patients who fulfilled the inclusion criteria did not respond to our invitation, declined to participate, or else could not be contacted. The mean age of the patients was 32.82 $\pm$ 11.81 years (range 19 to 62). There were 18 males and five females. There were 17 dominant and six non-dominant hands. The mode of injury was motor vehicle accident in 18 patients, fall while walking in four patients, and assault in one patient. The fractures were classified on the basis of the Arbeitsgemeinschaft fur osteosynthesefragen (AO) classification. There were four AO type A3, nine type C2, and ten type C3.

Figure 1. Preoperative Radiographs Showing Unstable Distal End Radius Fracture

The patients were given general/regional anesthesia at the discretion of the anesthesiologist. All of the surgeries were performed under tourniquet control. The fracture was approached through the base of flexor carpi radialis as described by Henry et al. (11). All of the patients underwent open reduction and internal fixation with a 2.4 mm variable-angle locking plate (Synthes, Switzerland, marketed in India by Synthes India Pvt. Ltd.). The use of bone grafting or bone graft substitutes (G-Bone Surgiwear Pvt. Ltd. Shahjahanpur, India) was left at the discretion of the operating surgeon. The patients were advised for active finger movements in the immediate post-operative period. The wrist was immobilized in a plaster splint for one week. The splint was removed at one week and the patients were instructed by a physiotherapist regarding the standard range of motion exercises for the wrist and fingers.

The follow-up radiographic assessment consisted of serial radiographs. The specific radiographs included anteroposterior and lateral projections taken in the immediate post-operative period, at three weeks, at six weeks, and thereafter to assess fracture union and any fracture- or hardware-related complications (Figure 2). The quality of reduction was measured with a standard goniometer and

then classified as satisfactory in cases with a dorsal tilt < 10°, < 2 mm of radial shortening, and < 2 mm of joint surface step-off (12, 13).

The range of motion at the wrist joint was measured with the help of a goniometer. The grip strength was calculated using a digital hand dynamometer (Takei scientific instruments Co. Ltd., Japan). The patient was made to stand with his/her elbow at full extension and with the shoulder adducted and neutrally rotated. The grip strength was measured in kilograms and as a percentage of the normal strength of the other wrist. All of the functional parameters were recorded at six weeks and at the final follow-up. The functional outcome was evaluated using the objective and subjective criteria described by Gartland and Werley (14).

3.1. Statistical Analysis

Student's t-test was used to compare the results between patient groups, with statistical difference defined as 5% ($P \leq 0.05$).

4. Results

Based on our inclusion criteria, 23 patients were available for analysis in the present retrospective cohort study (Table 1). The mean duration of follow-up was 11.04 ± 2.47 months (range 6 to 15). Among the 23 patients enrolled in the study, five patients developed complications. One patient developed a hypertrophic scar that was treated conservatively, while two patients had superficial wound infections that were resolved with regular dressings and antibiotic administration for two weeks (oral cefuroxime 500 mg twice daily). There was screw misplacement in one patient, which remained asymptomatic at follow-up (Figure 3). Another patient developed carpal tunnel syndrome, which was managed with a nocturnal splint and the symptoms were resolved in three months. None of the patients experienced tendon rupture, malunion, or nonunion. A bone graft substitute was used in four patients, although autologous bone grafting was not performed in any case.

The radiological parameters during the immediate post-operative period were compared with those at the time of final follow-up, as outlined in Table 2. The average radial inclination loss was 0.68 mm, radial length was 0.1 mm, volar angle was 0.26°, and ulnar variance was 0.16 mm, although the change in indices was not statistically significant.

The clinical parameters (flexion, extension, supination, and pronation) as measured at eight weeks and at final follow-up revealed significant improvement (Table 3).

Table 1. Clinical Profile of Patients[a]

Clinical Profile	Data
Age, y	32.82 ± 11.81
Gender	
Male	17
Female	6
Mode of injury	
RTI	18
Fall	4
Assault	1
Type of fracture (AO classification)	
A3	4
C2	9
C3	10

Abbreviation: RTI, road traffic incident.
[a]Values are expressed as mean ± standard deviation or No.

According to Gartland and Werley's scoring system, 15 patients had excellent results and eight patients had good results. None of the patients had fair or poor results.

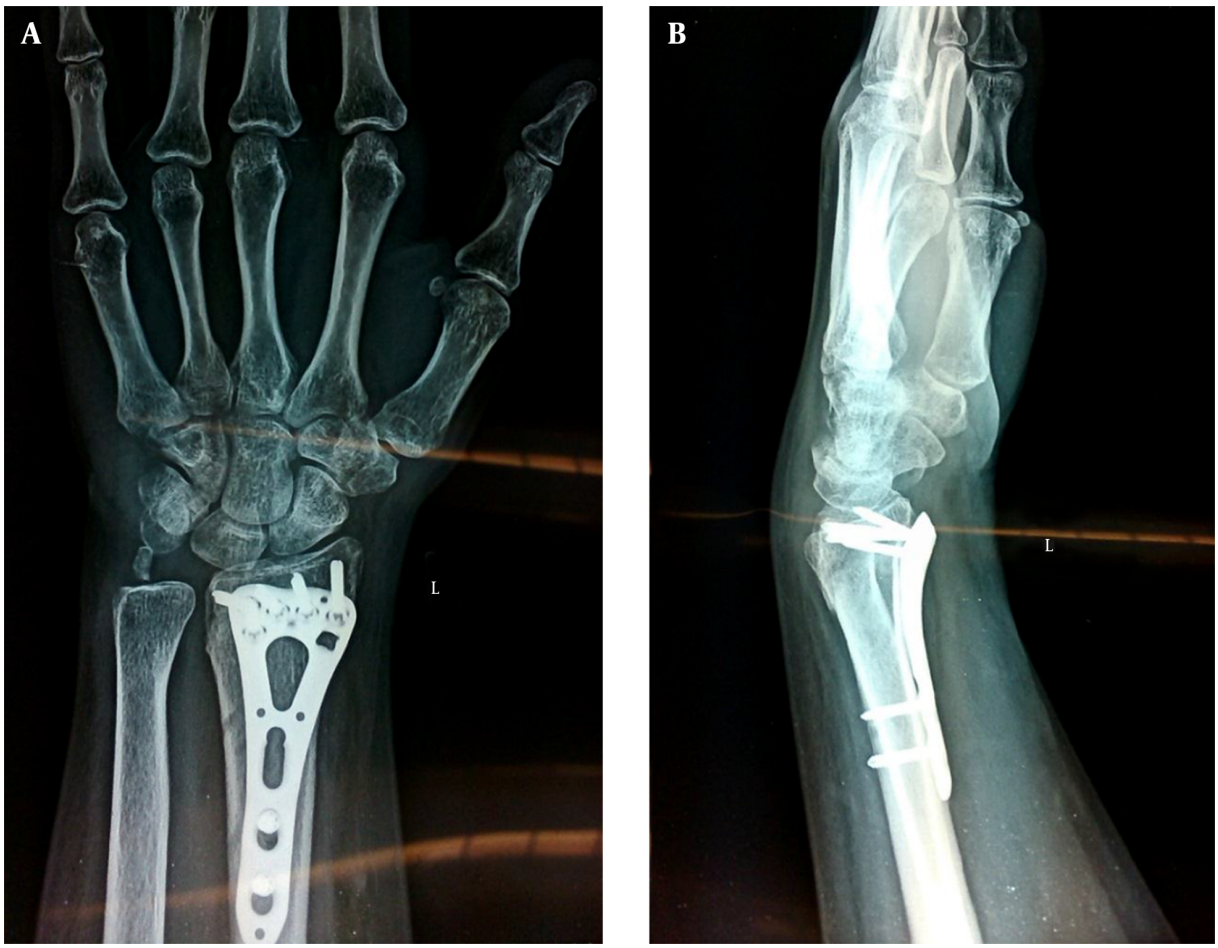
5. Discussion

The treatment of distal end radius fractures varies from closed reduction and casting in minimally displaced fractures to open reduction and internal fixation in more complex fractures. Open reduction and internal fixation restore the wrist's anatomy and help in faster rehabilitation with good clinical outcomes (15).

Volar plating is currently favored for comminuted distal end radius fracture patterns and osteoporotic bones (16). The volar cortex of the distal end radius is often less comminuted than the dorsal cortex; therefore, anatomical reduction of the palmar cortex restores the radial shortening. Moreover, the palmar cortex is better contoured with respect to the dorsal cortex in terms of plate application.

There had been a shift in focus from the use of non-locking volar plates to locking volar plates as the latter provides secure and reliable fixation of complex fractures due to angular stability (17, 18). Kanabar et al. (17) reported that early mobilization in fractures treated with volar fixed locking plates does not lead to a decrease in the radiological parameters achieved at the final follow-up (16). However, in their case series of comminuted distal end radius fractures, Gruber et al. noticed a statically significant loss in parameters like radial inclination and volar tilt with the use of volar fixed-angle plates (19). A few other studies have

Figure 2. Radiograph Showing Fracture Fixation With a Variable-Angle Locking Plate (at 14 Months Follow-Up)



A, Anteroposterior radiographic image of wrist showing fracture fixation with a variable-angle locking plate (at 14 months follow-up); B, lateral radiographic image of the same wrist showing maintained volar tilt at the time of last follow-up.

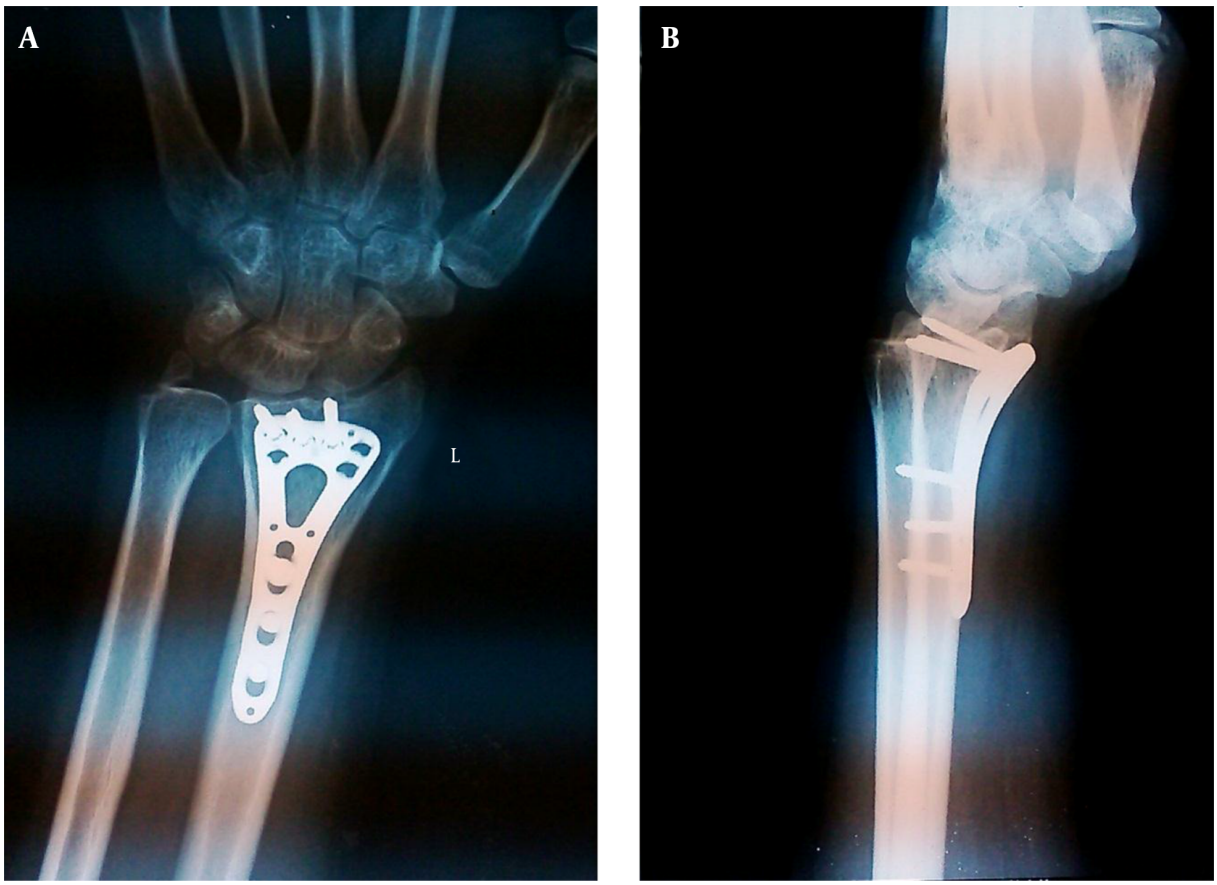
Table 2. Radiological Parameters[a,b]

Parameter	Immediate Postoperative Period	At Final Follow-Up	P Value
Radial length, mm	12.04 ± 1.91	11.84 ± 2.04	0.1309
Radial inclination,°	23.08 ± 2.46	22.89 ± 2.64	0.0951
Volar angulation, °	5.56 ± 5.54	5.21 ± 5.72	0.1334
Ulnar variance, mm	-0.33 ± 0.68	-0.29 ± 0.58	0.1337

[a]Values are expressed as mean ± standard deviation.
[b]There was no significant difference in the radiological parameters between different follow-ups.

also reported a reduction in the radiological parameters during the follow-up period with the use of volar fixed-angle plates (20, 21). The most significant change in parameters was seen in cases with comminuted distal end radius fractures (AO types C2 and C3). The introduction of variable angle plates addressed this problem in many such cases. There were concerns regarding the biomechanical rigidity of variable angle locking plates in comparison to fixed-angle plates. Stanbury et al. showed that the volar fixed and variable angle locking plates were similar in terms of

Figure 3. Radiograph Showing Screw Misplacement



A, Anteroposterior radiographic image of wrist showing screw misplacement in a case of unstable distal end radius treated with volar variable-angle locking plate; B, lateral radiograph of wrist confirming the screw misplacement suspected on anteroposterior radiograph.

Table 3. Clinical Outcome Measures[a]

Parameter	At Six Weeks	Final Follow-Up
Flexion,°	46.73 ± 7.24	71.91 ± 8.08
Extension, °	49.08 ± 6.28	76.95 ± 5.70
Pronation, °	72.04 ± 5.09	77.65 ± 6.01
Supination, °	75.47 ± 6.02	81.86 ± 6.28
Percentage grip power, %	41 ± 6.23	94.52 ± 5.02

[a]Values are expressed as mean ± standard deviation.

the mean load to failure on cyclical loading (22). The physiological compressive loads during movement of the wrist can easily be tolerated with VALPs.

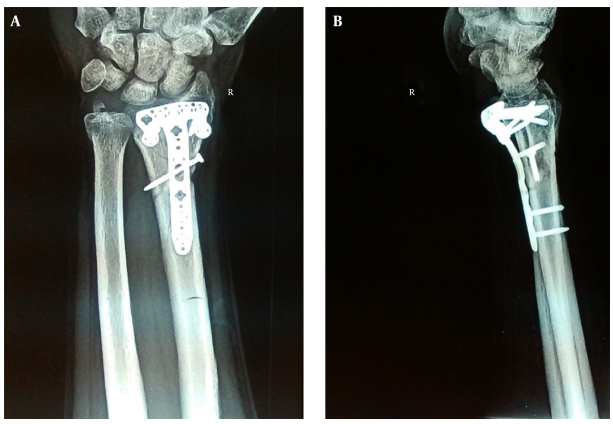
VALP allow subchondral purchase in the articular fragments due to the flexible plate positioning and so possibly maintain the reduction. In their case series on VALP, Figl et al. found no cases of a significant loss of radiological parameters in the follow-up period following fixation (23). Similarly, in our case series, the average loss in radial length, radial inclination, and volar angle, as well as the change in ulnar variance, were not significant at final follow-up in comparison to the immediate post-operative

period despite the early and aggressive rehabilitation.

Comminuted intra-articular radius fractures may require the placement of the volar plate distal near to the watershed line in order to capture the articular fragments; however, this could result in late flexor tendon rupture (24). A variable angle locking plate can be placed proximal to the watershed line and it is still able to engage those fragments. The bicortical purchase is another critical point in the management of complex fracture patterns and it can be achieved with flexible plate positioning in variable angle plates. The various fracture lines (proximal/distal and medial/lateral) are accommodated due to the flexibility offered by the variable angle system (25).

Various authors reported the use of additional methods like Kirschner wire and/or dorsal plating in a few comminuted fracture patterns (AO type C3) (26, 27). With the introduction of variable angle locking plates, there has been a decrease in the use of these additional methods of fixation. The adaptation of screw direction helps in engaging specific fracture fragments and avoiding intraarticular penetration. Stanbury et al. reported the superiority of variable angle volar locking plates over fixed-angle locking plates in capturing the distal radial styloid (22). However, in our case series, three cases required additional measures to stabilize the unstable distal end radius fracture. In two cases, Kirschner wire was used to engage small radial styloid fragments that could not be engaged with the plate screws, while in the other case a cortical screw was used to reduce a lateral column bony fragment to the medial column of the distal end radius (Figure 4) for the diaphyseal extension of the fracture.

Figure 4. Use of a Cortical Screw in Addition to a Volar Variable-Angle Locking Plate for Fracture Fixation



A, Anteroposterior radiograph of wrist showing use of a cortical screw in addition to a volar variable angle locking plate for fracture stabilization; B, lateral image of the same wrist revealing maintained radiographic parameters.

The volar variable angle locking plate is not a panacea for distal end radius fractures. The inability to decipher the articular anatomy of the distal end radius and the poor reduction of the fracture will lead to poor results with this newer implant. Complications such as hardware prominence, loss of reduction, and tendon irritation are similar to those found with other volar plates. The overall complication rate in our study was 21.7%, which is comparable to that reported by Jagodzinski et al. in a bicentric study on distal radius variable angle locking plates (28). They reported a complication rate of 19.6%, although the majority had screw misplacement, while Kawasaki et al. had no reported cases of screw misplacement (29). In our study, there was only one case of screw misplacement because extra care was taken to prevent this complication since it could have resulted in longer fluoroscopy time. However, no effort was made to calculate the resultant extra fluoroscopy exposure. The smaller sample size in our study could also be the reason for only a single case of such a complication.

The evaluation of our results according to Gartland and Werley's demerit scoring system revealed that 65.22% patients had excellent results, while 34.78% fell into the good results category (Figure 5). Figl et al. reported excellent results in 37.5% of patients, good results in 67%, and fair results in 1% (22). Jagodzinski et al. reported a mean DASH (disabilities of the arm, shoulder, and hand) score of 18.2 in patients treated with VALP (28). The results are, however, not truly comparable with those of the current study as a different scoring system was used in the evaluation of the results.

The minimum duration of follow-up in the present study was six months. MacDermid et al. reported that patients with distal end radius fractures achieve the majority of their grip strength and movement in six months (30). In their large series of 170 patients with distal end radius fractures, Kanabar et al. noticed that parameters such as range of motion and grip strength were regained by up to 94% in the three months after volar plating (17).

A limitation of the present study was that the retrospective cohort was treated at a tertiary care center with expertise in the management of these complex fractures. It is difficult to say whether the findings of this study can be generalized to patients managed at other centers. A large number of patients did not consent to participate in our study or else could not be traced due to an incomplete contact address or contact number. There was also a wide range of patient ages. Further, some of the patients could be osteopenic, although this was not assessed with dual-energy X-ray absorptiometry or a computerized tomography scan. It is difficult to compare the treatment outcomes of this study with those of other modalities of treatment as

Figure 5. Range of Movement at the Wrist After Eight Months in a Case Treated With a Variable-Angle Locking Plate (Radiograph as Depicted in Figure 3)

A, Clinical photograph of the patient with radiographs depicted in Figure 3; B, wrist extension at the time of last follow-up; C, good flexion movement at the same wrist joint.

we did not compare treatment methodologies. However, we believe that the data from the present study can be used for comparison in future studies.

In conclusion, variable volar locking plates are a treatment method with a low complication rate. The use of such plates helps in early rehabilitation without the fear of a decrease in radiographic indices and hence functional results. It could thus be a useful modality for managing unstable distal end radial fractures. Despite the small sample size, the present series should provide the basis for a future prospective study involving variable volar locking plates.

Footnote

Authors' Contribution: Kavin Khatri and Vijay Sharma developed the original idea for the study and the protocol. Kavin Khatri abstracted and analyzed the data, wrote the manuscript, and acts as the corresponding author. Vijay Sharma, Kamran Farooque, and Vivek Tiwari contributed to the development of the protocol and the preparation of the manuscript. All of the authors read and approved the final manuscript.

References

1. Xavier CR, Dal Molin DC, Dos Santos RM, Dos Santos RD, Neto JC. Surgical Treatment of Distal Radius Fractures with a Volar Locked Plate: Correlation of Clinical and Radiographic Results. *Rev Bras Ortop.* 2011;**46**(5):505–13. doi: 10.1016/S2255-4971(15)30404-3. [PubMed: 27027046].
2. Arora R, Gabl M, Gschwentner M, Deml C, Krappinger D, Lutz M. A comparative study of clinical and radiologic outcomes of unstable colles type distal radius fractures in patients older than 70 years: nonoperative treatment versus volar locking plating. *J Orthop Trauma.* 2009;**23**(4):237–42. doi: 10.1097/BOT.0b013e31819b24e9. [PubMed: 19318865].
3. Wong KK, Chan KW, Kwok TK, Mak KH. Volar fixation of dorsally displaced distal radial fracture using locking compression plate. *J Orthop Surg (Hong Kong).* 2005;**13**(2):153–7. [PubMed: 16131677].
4. Ring D, Jupiter JB, Brennwald J, Büchler U, Hastings H. Prospective multicenter trial of a plate for dorsal fixation of distal radius fractures. *J Hand Surg Am.* 1997;**22**(5):777–84. doi: 10.1016/s0363-5023(97)80069-x.
5. Osada D, Viegas SF, Shah MA, Morris RP, Patterson RM. Comparison of different distal radius dorsal and volar fracture fixation plates: a biomechanical study. *J Hand Surg Am.* 2003;**28**(1):94–104. doi: 10.1053/jhsu.2003.50016. [PubMed: 12563644].
6. Rausch S, Klos K, Gras F, Skulev HK, Popp A, Hofmann GO, et al. Utility of the cortical thickness of the distal radius as a predictor of distal-radius bone density. *Arch Trauma Res.* 2013;**2**(1):11–5. doi: 10.5812/atr.10687. [PubMed: 24396783].
7. Ross M, Heiss-Dunlop W. In: Volar angle stable plating for distal radius fractures. Slutsky DJ, editor. ; 2010.
8. Albertoni WM, De Paula EJL, Toledo LF, MQ GGD, Freitas A. Unstable fractures of the distal radius: a multicentric study. *Rev Bras Ortop.* 2002;**37**(10):436–44.
9. Cooney WP, Dobyns JH, Linscheid RL. Complications of Colles' fractures. *J Bone Joint Surg Am.* 1980;**62**(4):613–9. [PubMed: 6155380].
10. Lafontaine M, Hardy D, Delince P. Stability assessment of distal radius fractures. *Injury.* 1989;**20**(4):208–10. [PubMed: 2592094].
11. Henry AK. extensile exposures. edinburgh. Churchill Livingston; 1973.
12. Trumble TE, Schmitt SR, Vedder NB. Factors affecting functional outcome of displaced intra-articular distal radius fractures. *J Hand Surg Am.* 1994;**19**(2):325–40. doi: 10.1016/0363-5023(94)90028-0. [PubMed: 8201203].
13. Nana AD, Joshi A, Lichtman DM. Plating of the distal radius. *J Am Acad Orthop Surg.* 2005;**13**(3):159–71. [PubMed: 15938605].
14. Gartland JJJr, Werley CW. Evaluation of healed Colles' fractures. *J Bone Joint Surg Am.* 1951;**33-A**(4):895–907. [PubMed: 14880544].
15. Park JH, Hagopian J, Ilyas AM. Variable-angle locking screw volar plating of distal radius fractures. *Hand Clin.* 2010;**26**(3):373–80. doi: 10.1016/j.hcl.2010.04.003. [PubMed: 20670802].
16. Margaliot Z, Haase SC, Kotsis SV, Kim HM, Chung KC. A meta-analysis of outcomes of external fixation versus plate osteosynthesis for unstable distal radius fractures. *J Hand Surg Am.* 2005;**30**(6):1185–99. doi: 10.1016/j.jhsa.2005.08.009. [PubMed: 16344176].
17. Kanabar P, Mirza S, Hallam P, Cooper A. Volar locking plate for distal radius fractures: does it do what it says on the box? A radiological review of 170 consecutive distal radius fractures treated with a volar locking plate. *J Bone Joint Surg Br.* 2011:93.
18. Levin SM, Nelson CO, Botts JD, Teplitz GA, Kwon Y, Serra-Hsu F. Biomechanical evaluation of volar locking plates for distal radius fractures. *Hand (N Y).* 2008;**3**(1):55–60. doi: 10.1007/s11552-007-9063-1. [PubMed: 18780122].
19. Gruber G, Gruber K, Giessauf C, Clar H, Zacherl M, Fuerst F, et al. Volar plate fixation of AO type C2 and C3 distal radius fractures, a single-center study of 55 patients. *J Orthop Trauma.* 2008;**22**(7):467–72. doi: 10.1097/BOT.0b013e318180db09. [PubMed: 18670287].
20. Rozental TD, Blazar PE. Functional outcome and complications after volar plating for dorsally displaced, unstable fractures of the distal radius. *J Hand Surg Am.* 2006;**31**(3):359–65. doi: 10.1016/j.jhsa.2005.10.010. [PubMed: 16516728].
21. Orbay JL, Fernandez DL. Volar fixed-angle plate fixation for unstable distal radius fractures in the elderly patient. *J Hand Surg Am.* 2004;**29**(1):96–102. [PubMed: 14751111].

22. Stanbury SJ, Salo A, Elfar JC. Biomechanical analysis of a volar variable-angle locking plate: the effect of capturing a distal radial styloid fragment. *J Hand Surg Am.* 2012;**37**(12):2488–94. doi: 10.1016/j.jhsa.2012.09.009. [PubMed: 23174062].
23. Figl M, Weninger P, Liska M, Hofbauer M, Leixnering M. Volar fixed-angle plate osteosynthesis of unstable distal radius fractures: 12 months results. *Arch Orthop Trauma Surg.* 2009;**129**(5):661–9. doi: 10.1007/s00402-009-0830-z. [PubMed: 19225792].
24. Asadollahi S, Keith PP. Flexor tendon injuries following plate fixation of distal radius fractures: a systematic review of the literature. *J Orthop Traumatol.* 2013;**14**(4):227–34. doi: 10.1007/s10195-013-0245-z. [PubMed: 23670492].
25. Couzens GB, Peters SE, Cutbush K, Hope B, Taylor F, James CD, et al. Stainless steel versus titanium volar multi-axial locking plates for fixation of distal radius fractures: a randomised clinical trial. *BMC Musculoskelet Disord.* 2014;**15**:74. doi: 10.1186/1471-2474-15-74. [PubMed: 24612524].
26. Rikli DA, Regazzoni P. Fractures of the distal end of the radius treated by internal fixation and early function. A preliminary report of 20 cases. *J Bone Joint Surg Br.* 1996;**78**(4):588–92. [PubMed: 8682826].
27. Benson LS, Minihane KP, Stern LD, Eller E, Seshadri R. The outcome of intra-articular distal radius fractures treated with fragment-specific fixation. *J Hand Surg Am.* 2006;**31**(8):1333–9. doi: 10.1016/j.jhsa.2006.07.004. [PubMed: 17027796].
28. Jagodzinski NA, Singh T, Norris R, Jones J, Power D, editors. Early results of a variable-angle volar locking plate for distal radius fractures: A bi-centre study. Orthopaedic Proceedings. 2012; Orthopaedic Proceedings.
29. Kawasaki K, Nemoto T, Inagaki K, Tomita K, Ueno Y. Variable-angle locking plate with or without double-tiered subchondral support procedure in the treatment of intra-articular distal radius fracture. *J Orthop Traumatol.* 2014;**15**(4):271–4. doi: 10.1007/s10195-014-0292-0. [PubMed: 24942842].
30. MacDermid JC, Roth JH, Richards RS. Pain and disability reported in the year following a distal radius fracture: a cohort study. *BMC Musculoskelet Disord.* 2003;**4**:24. doi: 10.1186/1471-2474-4-24. [PubMed: 14588078].