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ORIGINAL STUDY

Distal radius volar locking plates : Does a variable angle locking system confer a clinical advantage ?

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This retrospective study compared clinical, radiological and subjective outcomes between patients with a distal radius fracture fixed with a variable angle or fixed angle volar locking plate.

Radiological parameters were assessed between initial and final post-operative films. Post-operative clinical range of motion as a proportion of that in the opposite wrist was assessed clinically, and satisfaction and subjective outcomes were assessed by questionnaire.

One hundred and seven patients were included in the study ; 65 underwent fixation with a variable angle and 42 with a fixed angle locking plate. There were five complications and secondary operations in each group. There was no significant difference between the groups in radiological parameters measured or the proportional range of motion. Visual analogue scale, Mayo Wrist and Quick DASH scores were not significantly different between the groups.

Neither the subjective nor clinical outcomes of this study demonstrated clinical superiority of either plate system.

Keywords : distal radius fracture ; volar locking plate ; fixed angle ; variable angle.

INTRODUCTION

Treatment of unstable distal radius fractures is historically controversial. Operative treatment for such fractures include Kirschner (K-) wires with plaster cast (*10*), external fixation (bridging or non-bridging) (*1,3,7*) and open reduction and internal fixation (*6,17*). Open reduction and internal fixation includes dorsal or volar fixation (or both). The volar approach to the distal radius gained popularity due to lower incidences of tendon related problems and the lack of comminution on the volar surface aiding fracture reduction (*12,14,20,22,29*).

With the advent of locking plate technology, the potential biomechanical advantages, especially for fixation in osteoporotic bone, are clear (*13*). In the 1990's, the first fixed angle plates designed for volar placement were introduced as an alternative to dorsal plating (*19*). The volar locking plate has subsequently become increasingly popular over recent years (*5,13*). Several designs of volar locking plates are available today. One design option is between variable and fixed angle locking of screws into the plate.

The volar fixed angle plate provides fixation by buttressing the metaphyseal curvature while provid-

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ing fixed-angle cantilever support of the distal subchondral bone without the need for bone grafting. Proximally, the plate connects to the intact volar cortex of the diaphysis ; therefore, the fixed angle plate transfers the force from the distal support pegs to the shaft of the radius while accounting for the natural volar angle, thus restoring the complex anatomy of the distal radius (*18*). The fixed angle plates used in this study have two distal rows designed to take fixed angle screws or smooth pegs (*18*) which produces a 3 dimensional scaffold to underpin the articular surface. McCall *et al* demonstrated the biomechanical superiority of these implants over dorsal locking implants (*15*).

Recently, distal radius plating systems with variable angle locking screws have been introduced. These fixation systems allow the surgeon to place the plate in the optimal buttressing position while permitting fine-tuning of screw angles to optimise fixation and avoid disruption of the articular surface. The variable angle locking plates in this study permit a deviation of up to ± 15 degrees in any direction from neutral. They employ a 3-point wedge locking system, which results in a friction-locked connection due to radial tensioning of the screw head in the plate.

The purpose of this study was to compare the clinical and radiological outcomes of fixed angle and variable angle plate fixation for unstable distal radius fractures.

PATIENTS AND METHODS

We conducted a retrospective comparative study in patients who had undergone distal radius fracture fixation under the care of the two senior authors. Two plate designs were used. Those patients treated with the 1.6 mm thick "Aptus" (Medartis, Switzerland) variable angle locking plate were termed "Group V" ; those treated with the 2.5mm thick "DVR" (DePuy, Warsaw, IN, USA) fixed angle locking plate were termed "Group F". Patients were not randomised ; the plate used was dependent on which system was available at the time. Inclusion criteria for the study were consecutive skeletally mature patients who had undergone fixation of a distal radius fracture. Indications for surgical treatment were the inability to reduce a fracture and/or maintain reduction by closed means or in the presence of an inherently unstable fracture configuration. Surgery was performed by, or under the supervision of either of the senior authors. Data was collected on the following variables : demographics, type of fracture, associated injuries, type of plate used, length of stay, duration of total follow-up, complications and consequent secondary procedures undertaken.

Surgical technique : The procedure was performed under general anaesthesia and with an arm tourniquet. Patient position was supine with the injured arm on the arm board. The flexor carpi radialis (FCR) approach used was through the bed of the FCR tendon (*18*). Pronator quadratus muscle was released from the radial and distal borders and the fracture site was exposed. Anatomical reduction was achieved by ligamentotaxis and direct manipulation. In cases of difficult reduction, the brachioradialis was released from the radial styloid. After checking the reduction under image intensifier, a volar locking plate was applied and provisionally held with K-wires through the holes provided in the implant. The position was checked under image intensifier and, if satisfactory, the proximal oval gliding hole was filled first with a non-locking screw to allow for longitudinal adjustment. With the fixed angle plate, smooth pegs were used in the proximal and distal rows of the plate. In the variable angle plate, distal locking screws were placed in both rows using the drill guide provided. Lastly, the proximal screws were placed and final position was checked with image intensifier. The wrist was immobilised for two weeks and gentle active exercises were commenced after that period. Post operative radiographs of the operated wrists were performed to assess the adequacy of reduction and placement of the plate.

Radiological assessment compared immediate post-operative radiographs to radiographs taken at final follow-up. Parameters assessed were dorsal tilt, radial inclination and radial length. The dorsal tilt was measured as dorsal deviation from the normal volar angle of 11 degrees. The immediate post op radiograph measurements were compared to the radiographs taken at final follow up.

Objective outcomes were measured in the Occupational Therapy (OT) clinic at final follow-up and subjective outcomes were later measured by postal questionnaire. Objective clinical outcome was assessed by measuring the range of movements including wrist flexion and extension, radial and ulnar deviation, and forearm supination and pronation. Grip strength was measured using a Jamar dynamometer. Subjective wrist outcomes were assessed using the Mayo Wrist Score and Quick DASH score. Patient satisfaction was assessed by a Visual Analogue Scale (VAS) of overall satisfaction with the procedure, willingness to undergo the same procedure in the future and willingness to recommend the procedure to a friend or relative.

Statistical analysis was conducted using SPSS 16 (Chicago, Illinois, USA). Student's t-test was used to test for significance of inter- and intra-cohort differences in continuous variables. Chi-squared or Fisher's Exact test was used to assess the rate of complications. A p-value of < 0.05 was considered significant.

RESULTS

Of the 119 patients who underwent distal radius fracture fixation between November 2006 and June 2010, twelve were not included. Seven patients were excluded due to the presence of additional ipsilateral bony injuries, one patient had previously undergone trapeziectomy in the ipsilateral wrist, two patients were lost to follow-up and two patients transferred to another region for further follow-up. A total of 107 patients were therefore included in the study ; of these, 65 underwent variable angle plate fixation (group V) and 42 underwent fixed angle plate fixation (group F).

The demographics, AO sub-classification of fracture and timing of operation and objective assessments were similar in each group although the subjective assessments were significantly later in group F (Table I).

Figure 1 illustrates an AO classification 23 C2.2 fracture in a 23-year-old male and its fixation with a variable angle locking plate. Figure 2 demonstrates a 23 C3.1 fracture in a 55-year-old female which is stabilised with a fixed angle device.

Three patients (4.6%) in group V stated they would neither have the same operation again nor would they recommend the operation to a relative. All the patients from the group F would have the operation again but two patients (4.8%) would not recommend this operation for their relatives. The VAS scores were similar in the two groups, as were the Mayo Wrist and the Quick DASH scores. None of the subjective parameters were found to be statistically significantly different between the two groups (Table II).

Objective range of movement in each direction was expressed as a percentage of the movement of the normal (opposite) wrist. This demonstrated a trend towards the DVR group having a superior range of movement which was statistically significant in the case of ulnar deviation (p value = 0.002) (Table III). The mean grip strength was 53.3 kg in group V and 58.4 kg in group F (p = 0.493).

The mean dorsal tilt, radial inclination and radial length were calculated for each group on both immediate post-operative and final follow-up radiographs. For each plate, there was no significant difference in dorsal tilt, radial inclination or radial length between the two radiographs (Table IV).

Table I. — Demographics, fracture sub-classification and timing of operation and assessments in each group

	Group V	Group F
Total number of patients	65	42
Female : Male	51:14	30:12
Dominant side involved	16	9
Mean age at operation (Range)	57.7 (17.5-92)	56.1 (18.6-87)
AO Type- A	15 (23.07%)	12 (28.57%)
AO Type B	5 (7.69%)	3 (7.142)
AO Type C	45 (69.23%)	27 (64.28%)
Injury to operation time	5.73 days (0-22)	6.5 days (0-28)
Length of stay	1.6 days (0-22)	2.13 days (0-17)
Mean time to objective assessment	7.5 months (4- 13)	7.8 months (4-18)
Mean time to subjective assessment	17.2 months (7-20)	32.5 months (14-54)

Fig. 1. — An illustrative case of fixation of a left distal radius fracture in a 23-year-old male with a variable angle locking plate.
A) Pre-operative PA and Oblique radiographs : AO Classification : 23 C2.2
B) Immediate post-operative PA and Lateral radiographs
C) 3 months post-operative PA and Lateral radiographs.

Comparing the change in each parameter between the two radiographs, there was no significant difference between the two plates.

A total of 5 (7.69%) complications were observed in group V. Two patients had reduced range of movements requiring plate removal which subjectively improved this restriction in both patients. One patient developed carpal tunnel syndrome 4 months post-fixation and underwent carpal tunnel decompression. Two patients presented with complex regional pain syndrome (CRPS), both of whom underwent removal of metalwork and their symptoms resolved with a course of physiotherapy.

A total of 5 (11.91%) complications were observed in group F. Two patients presented with reduced range of movement associated with flexor tendon dysfunction and underwent removal of the metal work and flexor tenolysis at 12 and 13 months following the primary procedure. One patient developed extensor tendonitis 24 months subsequent to the primary procedure due to one prominent diaphyseal screw necessitating implant removal. One patient developed malunion which was successfully treated with osteotomy and fixation with a variable angle locking plate 3 months

Fig. 2. — An illustrative case of fixation of a left distal radius fracture in a 55-year-old female with a fixed angle locking plate.
A) Pre-operative AP and Lateral radiographs : AO classification 23 C3.1
B) Immediate post-operative PA and Lateral radiographs
C) 3 months post-operative PA and Lateral radiographs.

after primary fixation. The displacement and malunion occurred due to screw cut-out in a highly comminuted fracture. Another patient developed non-union at the fracture site 9 months after primary fixation and underwent revision plating with the use of bone graft. The EPL tendon was also found to be tethered but not ruptured. The metalwork was subsequently removed 17 months after the primary procedure due to reduced range of movement.

DISCUSSION

Our experience of treating unstable distal radius fractures with volar locking plates has been presented. This study compares two different designs of volar locking plates. While the DVR plate maintains the reduction according to a pre-determined 3-dimensional construct, Aptus plates have flexible angle locking screws.

Subjective outcome scores were similar between the two groups. Range of motion in each direction and grip strength were similar in the two groups. Analysis of radiographs demonstrated structural stability between initial and final follow-up films and similar changes in each parameter with each

Table II. — Mean score for each subjective scale in each group

	Group V (n = 58)	Group F (n = 38)	
Subjective parameter	Mean (SD)	Mean (SD)	p value
VAS	8.43 (1.98)	8.24 (2.44)	0.330
Mayo Wrist Score	71.83 (17.96)	79.44 (16.60)	0.063
Quick DASH Score	20.14 (0-81)	21.39 (0-88.6)	0.225

Table III. — Mean range of motion in each direction as a proportion of that found in the normal (opposite) side

	Group V (n = 58)	Group F (n = 38)	
Objective parameter	Mean ± SD	Mean ± SD	p-value
% Flexion	75.6 ± 19.79	82.4 ± 19.08	0.291
% Extension	83.6 ± 16.30	85.8 ± 15.66	0.829
% Radial Deviation	82.6 ± 27.98	88.3 ± 15.01	0.526
% Ulnar Deviation	76.7 ± 21.01	95.7 ± 4.78	0.002
% Pronation	95.5 ± 6.31	97.9 ± 4.07	0.417
% Supination	86.7 ± 24.21	94.8 ± 13.75	0.134

Table IV. — Radiological Outcomes : Dorsal tilt, Radial inclination and Radial length

Group	Immediate post-operative radiographs	Final follow up radiographs	p-value
Dorsal Tilt in degrees (Mean ± Std Dev)			
Group V	8.2 ± 8.56	9.1 ± 8.14	0.17
Group F	5.8 ± 4.41	6.1 ± 4.82	0.56
Radial Inclination in degrees (Mean ± Std Dev)			
Group V	19.7 ± 5.51	19.5 ± 5.54	0.670
Group F	22.2 ± 3.86	22.9 ± 3.45	0.102
Radial Length in mm (Mean ± standard deviation)			
Group V	7.6 ± 3.91	7.3 ± 3.86	0.220
Group F	8.5 ± 3.07	8.9 ± 3.54	0.509

plate. A similar number of complications and secondary operations occurred in each group.

Each of the subjective outcome measures, the VAS, Mayo Wrist Score and Quick DASH score in addition to the rate of patients prepared to undergo the operation again or recommend it to a relative was similar between the two groups. The range of Mayo Wrist and Quick DASH Scores recorded are not dissimilar from those seen in the literature (*9,23,25*).

Range of motion in each direction was not statistically different between the two groups except range of ulnar deviation which was significantly lower in group V. There was no clear explanation for this ; the standard plate head width is 23 mm in the Aptus plate and 24.4 mm in the DVR plate and there are no prominent screw heads on either design. Previous studies of the Aptus plate have demonstrated a good range of ulnar deviation (*16,26,27*) comparable to the 95.7% seen in the DVR plates in this study. The range of motion in other directions was comparable with the literature for both plates (*16,26,27*). Vlcek *et al* (*26*) compared the performance of this variable angle locking plate to another fixed angle plate and reported an improved range of radial and ulnar deviation with the variable angle device. Despite these inconsistencies, it does not seem that the use of variable or fixed angle locking devices has a clear and clinically significant effect on range of motion.

Radiographically, both plates demonstrated good stability in fixation from operation to final follow-up. Biomechanical testing of both plates used in this study has demonstrated them to have good strength under peak load to failure and after fatigue cycling (*24,28*). The dorsal tilt, and radial inclination and radial length are similar to those seen in previous studies (*16,21,27*). There was no significant difference between in the two plates in the amount which each parameter changed between the two radiographs.

There were 5 complications and 5 secondary surgical procedures in each group (7.7% in group V and 11.9% in group F) and this was not statistically significant. Arora *et al* studied the complications related to fixed angle implants used for distal radius fractures (*2*). This study reported an overall complication rate of 27% (31/114), including flexor and extensor tendon irritation and rupture, carpal tunnel syndrome, complex regional pain syndrome, hardware problems and delayed fracture union. Neither the overall rate of complications nor rate of tendon impingement were significantly different compared to the rates seen in our series of DVR plates when analysed by Chi-squared or Fisher's exact tests respectively.

Ideal treatment of unstable distal radius fractures is yet to be defined (*4,8*), but there has been a great enthusiasm towards new implant designs (*11*). The recent trend towards volar plating systems with variable angle distal locking screws has the advantage of allowing the surgeons to orient screws to avoid crossing articular surfaces and allowing more precise capture of fragments. It has been noted that very distal plate placement may cause impingement on the flexor tendon mechanism and that distal row screws may penetrate into the radiocarpal joint (*22*). However, the flexibility of variable angle locking screws may allow placement of the plate proximal to the watershed line while still acquiring solid fixation of distal fragments and avoiding penetration of the subchondral bone. Thus this new plating system has theoretical advantages in fixation of comminuted fractures and reconstruction of the complex geometry of the distal radius' articular surface while avoiding tendon irritation and joint penetration.

The limitation of our study is that it is retrospective. The patients were not randomised into the two groups, both plate systems were used concurrently and choice of implant was predominantly based on availability. The grade of surgeon performing the procedure was varied and although the patients in the two groups were comparable, they were not age and sex matched.

CONCLUSION

Complex and unstable fractures of the distal radius can be optimally managed with volar locking plates. Both variable angle and fixed angle locking plate designs are effective in maintaining radiological reduction of complex distal radius fractures and both systems are user friendly. In this study, there was no significant difference in Satisfaction, DASH or Mayo Wrist Scoring. Objective range of motion was similar for both groups. Rate of complications and secondary operation in each group was not significantly different. Variable angle locking plates may provide the potential advantage of flexibility in implant positioning and enhanced intra-fragmentary fixation in certain fractures. However, neither subjective nor objective outcomes demonstrated clinical superiority.

REFERENCES

1. **Anderson JT, Lucas GL, Buhr BR.** Complications of treating distal radius fractures with external fixation : a community experience. *Iowa Orthop J* 2004 ; 24 : 53-59.
2. **Arora R, Lutz M, Hennerbichler A *et al.*** Complications following internal fixation of unstable distal radius fracture with a palmar locking-plate. *J Orthop Trauma* 2007 ; 21 : 316-322.
3. **Clyburn TA.** Dynamic external fixation for comminuted intra-articular fractures of the distal end of the radius. *J Bone Joint Surg* 1987 ; 69-A : 248-254.
4. **Diaz-Garcia RJ, Oda T, Shauver MJ, Chung KC.** A systematic review of outcomes and complications of treating unstable distal radius fractures in the elderly. *J Hand Surg* 2011 ; 36-A : 824-835 e2.

5. **Downing ND, Karantana A.** A revolution in the management of fractures of the distal radius ? *J Bone Joint Surg* 2008 ; 90-B : 1271-1275.
6. **Gereli A, Nalbantoglu U, Kocaoglu B, Turkmen M.** Comparison of palmar locking plate and K-wire augmented external fixation for intra-articular and comminuted distal radius fractures. *Acta Orthop Traumatol Turc* 2010 ; 44 : 212-219.
7. **Haddad M, Rubin G, Soudry M, Rozen N.** External fixation for the treatment of intra-articular fractures of the distal radius : short-term results. *Isr Med Assoc J* 2010 ; 12 : 406-409.
8. **Handoll HH, Madhok R.** Surgical interventions for treating distal radial fractures in adults. *Cochrane Database Syst Rev* 2003 : CD003209.
9. **Hems TE, Rooney B.** Open reduction and plate fixation of dorsally displaced fractures of the distal radius : surgical technique, clinical and radiological outcome. *J Hand Surg Eur Vol* 2010 ; 35 : 56-60.
10. **Hollevoet N, Vanhoutie T, Vanhove W, Verdonk R.** Percutaneous K-wire fixation versus palmar plating with locking screws for Colles' fractures. *Acta Orthop Belg* 2011 ; 77 : 180-187.
11. **Hull P, Baraza N, Whalley H, Brewster M, Costa M.** Dorsally displaced fractures of the distal radius – a study of preferred treatment options among UK trauma and orthopaedic surgeons. *Hand Surg* 2010 ; 15 : 185-191.
12. **Kamano M, Honda Y, Kazuki K, Yasuda M.** Palmar plating for dorsally displaced fractures of the distal radius. *Clin Orthop Relat Res* 2002 ; 397 : 403-408.
13. **Larson AN, Rizzo M.** Locking plate technology and its applications in upper extremity fracture care. *Hand Clin* 2007 ; 23 : 269-278, vii.
14. **Lucas GL, Fejfar ST.** Complications in internal fixation of the distal radius. *J Hand Surg* 1998 ; 23 : 1117.
15. **McCall TA, Conrad B, Badman B, Wright T.** Volar versus dorsal fixed-angle fixation of dorsally unstable extra-articular distal radius fractures : a biomechanic study. *J Hand Surg* 2007 ; 32 : 806-812.
16. **Mehling I, Meier M, Schlor U, Krimmer H.** [Multidirectional palmar fixed-angle plate fixation for unstable distal radius fracture.] (in German). *Handchir Mikrochir Plast Chir* 2007 ; 39 : 29-33.
17. **Murakami K, Abe Y, Takahashi K.** Surgical treatment of unstable distal radius fractures with volar locking plates. *J Orthop Sci* 2007 ; 12 : 134-140.
18. **Orbay J, Badia A, Khoury RK, Gonzalez E, Indriago I.** Volar fixed-angle fixation of distal radius fractures : the DVR plate. *Tech Hand Up Extrem Surg* 2004 ; 8 : 142-148.
19. **Orbay JL.** The treatment of unstable distal radius fractures with volar fixation. *Hand Surg* 2000 ; 5 : 103-112.
20. **Orbay JL, Fernandez DL.** Volar fixation for dorsally displaced fractures of the distal radius : a preliminary report. *J Hand Surg* 2002 ; 27 : 205-215.
21. **Orbay JL, Fernandez DL.** Volar fixed-angle plate fixation for unstable distal radius fractures in the elderly patient. *J Hand Surg* 2004 ; 29 : 96-102.
22. **Ring D, Jupiter JB, Brennwald J, Büchler U, Hastings H 2nd.** Prospective multicenter trial of a plate for dorsal fixation of distal radius fractures. *J Hand Surg* 1997 ; 22 : 777-784.
23. **Sato K, Furumachi K, Nishida J *et al.*** Comparison of the volar locking plate and the bridging external fixator in the treatment of distal radius fracture based on range of wrist motion assessed by functional radiography. *Med Sci Monit* 2010 ; 16 : CR207-212.
24. **Sobky K, Baldini T, Thomas K *et al.*** Biomechanical comparison of different volar fracture fixation plates for distal radius fractures. *Hand (N Y)* 2008 ; 3 : 96-101.
25. **Tyllianakis ME, Panagopoulos AM, Saridis A.** Long-term results of dorsally displaced distal radius fractures treated with the pi-plate : is hardware removal necessary ? *Orthopedics* 2011 ; 34 : e282-286.
26. **Vlcek M, Landor I, Visna P *et al.*** [Multidirectional screw fixation in the treatment of distal radius fractures using angle-stable plates.] (in Czech). *Acta Chir Orthop Traumatol Cech* 2011 ; 78 : 27-33.
27. **Vlcek M, Visna P.** [Six-month functional and X-ray outcomes of distal radius fractures managed using multidirectional locking plates.] (in Czech). *Rozhl Chir* 2008 ; 87 : 486-492.
28. **Weninger P, Dall'Ara E, Leixnering M *et al.*** Volar fixed-angle plating of extra-articular distal radius fractures – a biomechanical analysis comparing threaded screws and smooth pegs. *J Trauma* 2010 ; 69 : E46-55.
29. **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 : 153-157.