Variable-angle Locking Compression Plate Fixation of Distal Radius Volar Rim Fractures

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Introduction

The application of a volar buttress plate in open reduction and internal fixation (ORIF) for distal radius fractures provides both construct stability and recovery of wrist function.[1] A subset of distal radius fractures may propagate distal to the watershed line and involve the volar rim. These fractures have challenged current indications for fixed-angle volar plates.[2] Sufficient stabilization by buttressing this fragment requires placement of conventional volar locked plates distal to the watershed region. This far distal fixation strategy leads to plate prominence that may cause flexor tendon irritation. Furthermore, positioning these fixed angle devices far distally may also lead to inadvertent wrist joint penetration by distally directed screws.[3]

A variable-angle volar rim locking compression plate system (VA-LCP; Depuy-Synthes, West Chester, PA) was designed to be placed distal to the watershed line with a low-profile contour to prevent flexor tendon irritation. The VA-LCP system also has 15° off axis variable angle screws that may assist in avoiding penetrating the wrist joint. Furthermore, VA-LCP has distal radial and ulnar "teardrop" holes that may be used to augment fixation of the radial styloid, lunate facet, and distal radial-ulnar joint. The purpose of this study is to compare functional and radiographic outcomes of VA-LCP to traditional fixation strategies with fixed angle volar locking compression plates (FA-LCP).

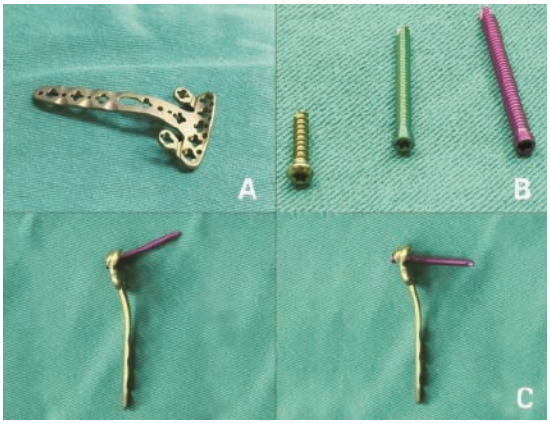

Figure 1. Variable angle locking compression plate for fragment-specific fracture fixation of fractures distal to the watershed line of the radius. **(A)**The pre-contoured variable angle volar rim plate (VA-LCP); **(B)** A 2.4 mm cortex screw and two 2.4 mm variable angle screws; **(C)** Low profile of the plate with holes allow up to 15° off-axis screw angulation in all directions.

Materials and Methods

A retrospective review of a consecutive series of patients who underwent open reduction and internal fixation (ORIF) using either VA-LCP (19 wrists) or traditional fixation with FA-LCP (28 wrists).

All patients underwent an extended volar approach of the distal radius to enable adequate visualization of the cortical rim of the distal radius.[4] In the FA-LCP group, a conventional volar locking plate was positioned as far distally as possible to stabilize the VMF. Auxiliary K-wires were added to augment fixation if stability was inadequate (Figure 1). In the VA-LCP group, a 2.4 mm VA-LCP low profile plating system was positioned straddling the watershed line, and held preliminarily in place with a K-wire in the distal end of the plate. The distal variable angle screws were placed as a "row of nails" to rafter and support the articular surface. Additional variable angle locking screws were placed in the radial and ulnar distal "teardrop" holes to augment fixation (Figure 2). Clinical outcomes were evaluated using the modified Mayo wrist score (MMWS), disabilities of the arm, shoulder, and hand (DASH) score, wrist range of motion (ROM) and grip strength relative to the uninjured contralateral side, and signs of flexor tendon irritation. Radiographic evaluation included radial height, radial inclination, volar tilt, and volar tear drop angle. All out comes were assessed at 3, 6, and 12 months postoperatively.

Results

The average follow-up period was 14.5 months (range 11-16 months) for the VA-LCP group and 15.8 months (range 12-18 months) for the FA-LCP group (Table 1). Both VA-LCP and FA-LCP groups improved MMWS and DASH scores with time postoperatively (Table 2). MMWS and DASH scores were improved in the VA-LCP group compared to the FA-LCP group at all time points after surgery ($p < 0.05$). Furthermore, relative ROM was improved in VA-LCP (flexion-extension 94.8%/ supination-pronation 93.8%) compared to the FA-LCP (flexion-extension 82.8%/ supination-pronation 84.5%) at 12 months ($p < 0.05$) (Figure 3). There was a 10.5%

Figure 2. Radiograph obtained pre-operatively and two days postoperatively in a 43-year-old man who had undergone ORIF using a FA-LCP. **(A)** Pre-operative images demonstrate an intra-articular comminuted volar marginal rim fracture; **(B)** Postoperative images after ORIF with FA-LCP.

(2/19) and 21.4% (6/28) incidence of flexor tendon irritation with VA-LCP and FA-LCP fixation respectively ($p < 0.05$). There was a greater decrease in volar tilt from initial postoperative radiographs to latest follow up in the FA-LCP group (2.75 degrees) compared to the VA-LCP group (1.68 degrees) ($p < 0.05$).

Discussion

Intra-articular distal radius fractures that involve the volar rim are challenging to manage. A volar marginal fragment (VMF) may be either too small or too distal to the watershed line to be adequately supported with traditional fixation strategies[2]. Although conventional volar locked plates may provide a stable reduction,[5, 6] the geometry of the lunate facet poses exceptional challenges. Harness et al. reported loss of fixation of a volar lunate facet fragment with carpal dislocation in a series of seven patients with an average of 24-months of follow-up.[7] The VA-LCP low profile plating system was designed to be placed distal to the watershed line with an anatomically pre-contoured geometry that allows supplemental fixation into the lunate facet. Thus, the purpose of this study is to compare outcomes of VA-LCP to traditional fixation strategies with FA-LCP.

This study shows differences in functional outcomes between VA-LCP and FA-LCP. MMWS and DASH were improved at all time points in the VA-LCP compared to FA-LCP group. As discussed in the limitations section, although these results were statistically significant, the clinical significance of this difference is less apparent. When assessing the relative wrist ROM, the VA-LCP had better recovery compared to FA-LCP. This difference in relative wrist ROM may contribute to the difference in MMWS.[8] However, the difference in relative wrist ROM may be confounded by different postoperative immobilization protocols. The FA-LCP group was immobilized for a longer period of time (6 weeks FA-LCP vs 1 week VA-LCP) because there was concern the fixation construct was less stable than that used for VA-LCP. This increased period of immobilization and delayed rehabilitation may have introduced a lag time bias. Longer follow up is needed to whether FA-LCP patients will recover more ROM to catch up to the VA-LCP group.

Relative grip strength was also improved in VA-LCP compared to FA-LCP at early follow up at 3 months. Again, this difference may have been related to the longer immobilization protocol and delayed rehabilitation in FA-LCP. Interestingly, the FA-LCP group recovered grip strength more rapidly after 3 months and we were unable to detect a difference in grip strength between both groups at 12 month follow up. However, there was an apparent difference in flexor tendon irritation between both groups. The FA-LCP group had a high incidence of flexor tendon irritation (21.4% FA-LCP versus 10.5% VA-LCP) and a re-operation rate for removal of hard ware (7.1% FA-LCP versus 0% VA-LCP). In the FA-LCP group, the conventional plate had to be positioned distal to the watershed line to adequately stabilize the lunate facet, which may have contributed to flexor tendon irritation. Furthermore, the supplemental K-wires used for fixation may have also injured the tendons. A cadaveric study by Chia et al, found that volar radial styloid, transverse radial, and dorso-ulnar K-wires may penetrate both tendons and nerves about the wrist.[9] Although VA-LCP also straddled the watershed line, the low profile anatomically contoured design with highly polished cambered surface may have contributed to a lower incidence of flexor tendon irritation.

In addition to differences in clinical outcomes, we observed differences in radiographic outcomes. Radial height, radial inclination, and volar tear drop angle were not found to be different between groups at all time points. There was a larger loss of volar tilt in FA-LCP group compared to VA-LCP. Although K-wire augmentation has been reported to be effective to enhance stability of the reduction in these fractures, their trajectory from radial to ulnar in direction are biomechanically inferior to a volar buttress for these fragments that may experience shearing forces.[10]

Table 1. Comparison of patient demographics between both groups.

	VA-LCP	FA-LCP	P value
Number of Patients	19	28	–
Male / Female	4M / 15F	6M / 22F	0.77
Age (years)	52.9 (42-65)	53.5 (39-66)	0.74
Dominant hand injured	9	12	0.73
Time between injury and surgery(days)	2.8 (2-5)	2.9 (2-5)	0.89

Table 2. MMWS and DASH functional outcome scores over the 12 month follow up visit.

	3 Months		6 Months		12 Months	
	MMWS	**DASH**	**MMWS**	**DASH**	**MMWS**	**DASH**
VA-LCP	76.3(70-85)	24.4(20-28)	93.3(80-100)	10.5(2-14)	93.8(85-100)	9.2(2-12)
FA-LCP	67.4(60-75)	31.7(25-34)	80.6(70-90)	14.1(8-20)	83.5(75-90)	12.8(6-18)
p value	0.02	0.04	<0.01	0.03	<0.01	0.02

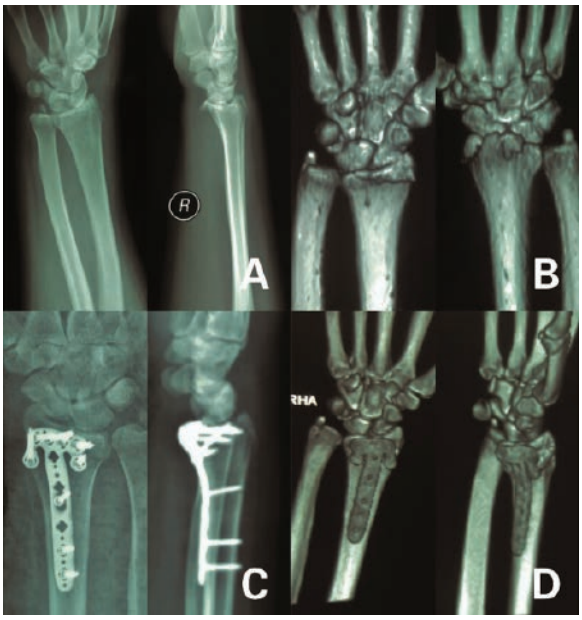

Figure 3. Radiograph obtained pre-operatively and two days postoperatively in a 49-year-old woman who had undergone ORIF using a VA-LCP. **(A)** Pre-operative images demonstrate an intra-articular distal volar marginal rim fracture with extension into the dorsal surface; **(B)** Postoperative images after ORIF with VA-LCP.

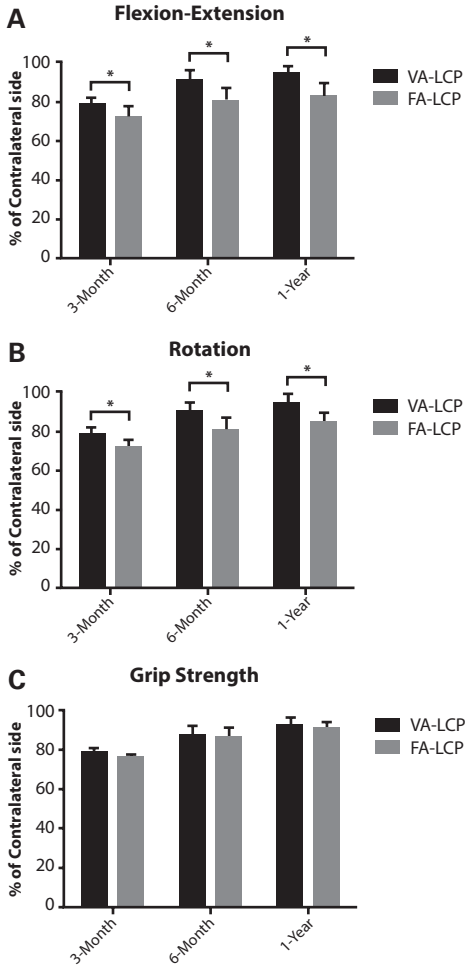

Figure 4. Relative ROM and grip strength throughout the 12 month follow up period. **(A)** Relative flexion-extension ROM **(B)** Relative supination-pronation ROM **(C)** Relative grip strength. *$p < 0.05$ when comparing between the two groups.

Conclusion

In conclusion, we report favorable clinical and radiographic results using the VA-LCP system compared to the FA-LCP. These results may be in part attributed to the VA-LCP system design with its low profile, anatomic contour, and multiple options for fixation that may decrease the incidence of joint penetration and improve lunate facet stability. Further research assessing the biomechanical properties of this system may further elucidate the mechanical properties of this plate and affect is has on the overlying flexor tendons. Furthermore, a long term prospective study is needed to assess long term clinical and radiographic implications when using this device compared to conventional plates. Surgeons should consider the VA-LCP system as an alternative to conventional plates when treating radius fractures distal to the watershed region.

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