



FUNCTIONAL OUTCOME OF INTRA-ARTICULAR FRACTURE DISTAL END RADIUS IN ADULT TREATED BY VARIABLE ANGLE VOLAR LOCKING PLATE

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ABSTRACT

Background: Intra-articular distal radius fractures present significant therapeutic challenges due to their complex anatomy and the need for precise restoration of articular congruity and wrist biomechanics. Variable-angle volar locking plates (VAVLPs) have been developed to improve fixation flexibility and stability, particularly in comminuted fracture patterns. **Objectives:** To evaluate the radiological and functional outcomes of intra-articular distal radius fractures in adults treated with variable-angle volar locking plate fixation, with emphasis on fracture union, functional recovery, and complications. **Methods:** This prospective observational study included 37 adult patients (aged 21–80 years) with intra-articular distal radius fractures (AO type B and C) treated with open reduction and internal fixation using VAVLPs over a one-year period. Patients were followed for up to 24 weeks. Radiological outcomes were assessed using Sarmiento's modification of Lindstrom's criteria, while functional outcomes were evaluated using the Modified Mayo Wrist Score. Range of motion, grip strength, fracture union, and complications were recorded. Statistical analysis was performed using SPSS version 22.0. **Results:** All fractures achieved union by 24 weeks, with a mean union time of 11.8 ± 2.3 weeks. Radiological outcomes were excellent or good in 89.2% of patients, with no statistically significant difference between AO type B and C fractures ($p = 0.668$). Functionally, 48.6% of patients had excellent and 40.5% had good outcomes ($p = 0.323$). At final follow-up, patients demonstrated near-normal wrist motion and a mean grip strength of 28.5 kg. Complications were minimal, with wrist stiffness (10.8%) being the most common. **Conclusion:** Variable-angle volar locking plate fixation provides reliable fracture union, excellent functional recovery, and a low complication rate in adult intra-articular distal radius fractures, making it an effective and versatile treatment option.

KEYWORDS : Distal Radius Fractures, Internal Fixators, Fracture Fixation, Internal Wrist Joint, Treatment Outcome

INTRODUCTION

Fractures of the distal end of the radius are among the most common skeletal injuries encountered in orthopedic practice. Representing approximately 15–20% of all fractures treated in emergency departments, they are particularly prevalent in two demographics: younger individuals involved in high-energy trauma and older adults with osteoporotic bones who sustain low-energy falls. These fractures, particularly when intraarticular, pose a significant challenge due to the complex anatomy of the distal radius and the need to restore both articular congruity and mechanical alignment to preserve wrist function.

The distal radius contributes significantly to wrist biomechanics, facilitating essential movements such as flexion, extension, pronation, and supination. Damage to this region, particularly within the articular surface, can result in significant disability, loss of hand function, and long-term morbidity including post-traumatic osteoarthritis.

Historically, non-operative management with closed reduction and casting was the mainstay of treatment for most distal radius fractures. However, conservative methods often resulted in malunion, stiffness, and poor functional outcomes, especially in unstable and displaced intraarticular patterns. Over the past two decades, the advent of volar locking plate technology has revolutionized the management of distal radius fractures. The biomechanical advantages, including angular stability, early mobilization, and superior control over fracture fragments, have led to increased adoption of this technique as the gold standard for many fracture types.

Among the innovations in volar plating systems, variable

angle volar locking plates have emerged as a significant advancement. Unlike traditional fixed-angle plates that constrain screw trajectories, variable angle systems allow the surgeon to place screws within a defined angular range, thereby enhancing the ability to target specific fracture fragments, especially in complex, comminuted, and intraarticular patterns. This adaptability provides enhanced fracture purchase and stabilization without compromising the soft tissue envelope. Additionally, the volar approach itself offers several benefits over dorsal plating, including decreased risk of extensor tendon irritation, reduced hardware prominence, and improved cosmesis.

Clinical outcomes following fixation with variable angle volar locking plates have been promising, with many studies demonstrating good to excellent results in terms of radiological alignment, range of motion, grip strength, and patient-reported functional outcomes. However, despite these advancements, challenges remain. Complications such as tendon irritation, hardware failure, malreduction, and persistent stiffness continue to be reported. Moreover, while radiographic union is often achieved, the correlation between anatomical reduction and functional recovery is not always linear, raising important questions about patient selection, surgical technique, and rehabilitation protocols.

While the biomechanical and radiological efficacy of variable angle volar locking plates is well-documented in cadaveric and laboratory settings, there remains a need for high-quality clinical studies that assess the real-world functional outcomes of patients treated with this technique. Specifically, there is a paucity of data in diverse patient populations, particularly in

low- to middle-income countries, where access to advanced implants and standardized rehabilitation services may be limited. As the global burden of orthopedic trauma continues to rise, particularly in urbanizing regions with increasing road traffic accidents and aging populations, the importance of contextually relevant clinical research cannot be overstated. This study was thus undertaken to evaluate the functional outcomes of intraarticular distal end radius fractures in adults treated using variable angle volar locking plates. The purpose of this study to analyze the efficacy of variable angle volar locking plate fixation of intra articular distal radius fractures in adults with special emphasis on technical difficulties and complications.

MATERIALS AND METHODS

The study was conducted in the Department of Orthopaedic Surgery at Dr. S.N. Medical College Hospital and included patients presenting with intra-articular distal radius fractures. It was carried out over a period of one year using a prospective observational study design. The study population comprised adult patients aged between 21 and 80 years.

Patients were included if they had intra-articular fractures of the distal end of the radius (AO type B, C1, C2), were between 21 and 80 years of age, had closed fractures or Grade I open fractures as per the Gustilo-Anderson classification, and presented within 10 days of injury. Patients were excluded if they were younger than 21 years or older than 80 years, had metabolic bone disorders, pathological fractures, underlying neuromuscular disorders, or were unwilling to provide consent.

A sequential sampling technique was employed, and all patients meeting the inclusion criteria and not falling under the exclusion criteria were enrolled. A total of 37 patients with intra-articular distal radius fractures were included in the study.

All surgeries were performed under tourniquet control. Open reduction and internal fixation with a variable-angle locking plate were carried out in all patients. Postoperatively, an above-elbow slab was applied, and patients were encouraged to maintain limb elevation along with active and passive finger mobilization exercises during the immediate postoperative period. Distal neurovascular status was monitored regularly. Intravenous antibiotics were administered for three days, followed by oral antibiotics until suture removal. Sutures and slabs were removed between the 10th and 14th postoperative day. Thereafter, patients were encouraged to perform active and passive wrist and finger exercises with a compression bandage, and resisted exercises were initiated approximately six weeks after surgery.

Patients were followed up at 4, 8, 12, and 24 weeks postoperatively. Routine radiographs were obtained to assess fracture healing. Radiological outcomes were evaluated using Sarmiento's modification of Lindstrom's criteria, and functional outcomes were assessed using the Modified Mayo Wrist Score.

For data collection and monitoring, patients presenting to the emergency department were initially assessed using the ABCDE (Airway, Breathing, Circulation, Disability, Exposure) approach. Once stabilized, they underwent surgical fixation with a distal radius plate. Intraoperative findings and postoperative follow-up details were systematically recorded in a structured proforma.

Ethical approval for the study was obtained from the Institutional Ethics Committee of Dr. S.N. Medical College, Jodhpur. Written informed consent was obtained from all participants prior to their inclusion in the study. All procedures

adhered to the ethical standards of the 1964 Helsinki Declaration and its subsequent amendments, and patient confidentiality was maintained throughout the study.

Statistical Analysis: The collected data were entered and analyzed using SPSS version 22.0 (IBM Corp., Armonk, NY, USA). Descriptive statistics were used to summarize patient demographics and clinical variables. Continuous variables were expressed as mean $\pm$ standard deviation, while categorical variables were presented as frequencies and percentages. Inferential statistical tests such as the Chi-square test and Student's t-test were applied where appropriate, with a p-value of <0.05 considered statistically significant.

RESULTS

The age distribution of the 37 patients revealed that the highest proportion fell in the 40–49 year age group, accounting for 27% of the cohort. This was followed by 21.6% in the 30–39 year group and 18.9% in the 50–59 year group. Both the 21–29 and the 60+ groups comprised 16.2% each. Out of the total 37 patients, 62.2% were male and 37.8% were female. According to the AO classification, 43.2% of patients had type B fractures, while 56.8% had type C fractures. Among the patients, 24.3% had hypertension, 16.2% had diabetes mellitus, 13.5% were smokers, 10.8% had osteoporosis, and 5.4% had hypothyroidism. (Table 1)

Fracture union was not observed at 2 weeks in any patient. By the 6th week, 32.4% showed evidence of union, increasing sharply to 89.2% at 10 weeks and achieving complete union in all patients by the 24th week. The mean union time was 11.8 ± 2.3 weeks. (Table 2)

Radiological outcomes were comparable between AO type B and type C fractures. Among type B fractures, 50% had excellent and 37.5% had good outcomes, while for type C, 42.9% were excellent and 47.6% were good. The p-value of 0.668 indicates no statistically significant difference between the two groups. (Table 3)

Functionally, 48.6% of all patients had excellent outcomes and 40.5% had good outcomes. While 62.5% of AO type B fractures achieved excellent functional results compared to 38.1% in type C, the difference was not statistically significant ($p = 0.323$). (Table 4)

At the 12-month follow-up, patients demonstrated near-normal wrist function. Mean palmar flexion was 75° , dorsiflexion was 71° , supination was 82° , and pronation was 80° . The average grip strength was 28.5 kg. (Table 5)

Complications were minimal. Wrist stiffness was reported in 10.8% of cases (higher in type C fractures), malunion in 2.7%, and superficial infection in 2.7%. No cases of implant breakage were noted. (Table 6)

DISCUSSION

This prospective observational study was conducted to evaluate the efficacy of variable-angle volar locking plate fixation in intra-articular distal radius fractures in adults, with a special focus on technical challenges and complications. The study involved 37 patients who were treated and followed for 24 weeks, assessing functional and radiological outcomes using standardized scoring systems and range of motion measurements.

The majority of patients in this study fell within the 40–49 year age group (27%), followed by those in the 30–39 and 50–59 year ranges. This trend aligned with findings from Fowler et al. (2013), whose cohort had a mean age of 57 years, indicating that middle-aged individuals represent a substantial proportion of cases requiring surgical fixation with volar

locking plates. Khatri et al. (2016) also reported a younger patient cohort with a mean age of 32.8 years, reinforcing the idea that this injury affects a broad age spectrum and that favorable outcomes with variable-angle plates are achievable across these age groups.

In the current study, 62.2% of patients were male, indicating a male predominance in intra-articular distal radius fractures. This finding was comparable to the demographic patterns observed in the work of Spiteri et al. (2017), who also noted a male majority in their cohort undergoing fixation with the DePuy Synthes variable-angle plate. These findings suggest that occupational and activity-related risks may predispose men more frequently to such fractures.

Most patients presented with AO type C fractures (56.8%), indicating a higher prevalence of complex intra-articular fractures. This distribution is consistent with Braziulis et al. (2013), who reported that type C fractures were more common and significantly associated with worse DASH scores at six months postoperatively. This underscores the necessity of precise anatomical reduction and stable fixation in these more complex injuries to achieve optimal outcomes.

Hypertension (24.3%) and diabetes (16.2%) were the most common comorbidities in the present study, with smaller proportions presenting with osteoporosis, smoking history, and hypothyroidism. The influence of such comorbidities on outcomes has been previously considered by Savings et al. (2019), who showed that elderly patients with comorbid conditions still achieved significantly better outcomes with volar locking plate fixation compared to nonoperative management. Similarly, Eikrem et al. (2021) concluded that comorbidities did not significantly alter radiographic or functional results in patients over 55 treated with locking plates. These findings suggest that VAVLP fixation remains effective even in the presence of common systemic illnesses.

Union was achieved in all patients by the 24th week, with a mean union time of 11.8 weeks. This is in agreement with Lal et al. (2023), who reported excellent radiological healing with a median Batra anatomical score of 90 and no cases of delayed union using variable-angle plates. Likewise, Bojanapu et al. (2024) documented complete union in their series without significant delay, further supporting the reliability of these implants in promoting bone healing. The absence of nonunion in this study reflects the mechanical stability offered by the variable-angle locking system.

The study revealed that 45.9% of patients achieved excellent radiological outcomes, with no statistically significant difference between AO type B and C fractures. This finding is supported by Nishiwaki et al. (2021), who reported that although fixed-angle plates showed slightly better volar tilt maintenance, both fixed- and variable-angle volar locking plates produced comparable radiological outcomes over a one-year period. Additionally, Fang et al. (2023) demonstrated effective radiographic maintenance using VAVLP in both extra-articular and intra-articular fractures, with minimal displacement and low risk of tendon rupture. These parallels reinforce the suitability of VAVLPs in achieving and preserving radiological alignment regardless of fracture complexity.

Functionally, 48.6% of patients in this study achieved excellent results, and 40.5% achieved good outcomes, with no significant difference between AO types. These outcomes are echoed in Khatri et al. (2016), who found 65.2% of patients achieved excellent results based on the Gartland and Werley score.¹⁴ Similarly, Abdel et al. (2022) reported that variable-angle plates led to superior functional scores compared to fixed-angle plates, including better range of motion and grip strength. Furthermore, Ruckstuhl et al. (2014) demonstrated sustained functional outcomes over 10 years using volar

plates, confirming long-term durability. Together, these findings validate the functional effectiveness of VAVLPs, even in complex intra-articular patterns.

At 12 months, patients in this study achieved near-normal range of motion and grip strength, with palmar flexion averaging 75°, dorsiflexion 71°, and grip strength 28.5 kg. These results are consistent with Huang et al. (2022), who found significantly improved grip strength and Mayo wrist scores in patients treated with the Acu-Loc VLP system. Additionally, Gou et al. (2021) showed that VLPs outperformed external fixation in terms of pain and DASH scores, though external fixation showed transiently better grip strength early on. This reinforces that, over the long term, VAVLPs restore functional strength and motion to near-normal levels.

The complication rate in this study was low, with stiffness (10.8%) being the most frequent, followed by superficial infection (2.7%) and one case of malunion. These outcomes are favorable compared to the complication profiles reported in Fowler et al. (2013), where hardware-related complications, such as screw loosening and tenosynovitis, were observed.¹³ Importantly, there were no cases of tendon rupture or implant breakage in this study, similar to findings by Spiteri et al. (2017) who reported no tendon ruptures and low complication rates with variable-angle plating systems.¹⁵ Chung et al. (2008), noted a higher incidence of carpal tunnel syndrome with VLPs compared to intramedullary nails, but such complications were not observed in this cohort.¹¹ The low rate of complications here reflects appropriate implant placement and adherence to surgical protocols.

The results from this study, when compared to multiple previous investigations, consistently support the use of variable-angle volar locking plates for intra-articular distal radius fractures. The radiological and functional outcomes observed mirror those in studies like Jayaram et al. (2023), which found ORIF with VLP to be superior to conservative treatment and other modalities in the short term, without increasing complication risks. Park et al. (2010) also emphasized the increasing preference for ORIF with volar plates, especially for intra-articular and osteoporotic fractures, due to better anatomical restoration and earlier mobilization.

CONCLUSION

This study demonstrates that variable-angle volar locking plates provide excellent radiological and functional outcomes in the treatment of intra-articular distal radius fractures in adults. With a 100% union rate by 24 weeks and a majority of patients achieving good to excellent functional recovery, VAVLPs prove to be a reliable and effective fixation method. The low complication rate further supports their safety and applicability across a broad patient demographic, including those with comorbid conditions. The study also shows that the outcomes are consistent across both AO type B and C fractures, emphasizing the versatility of this implant system. Although the study has its limitations—such as small sample size, single-center data, and short follow-up duration—the consistency of results with prior literature strengthens the case for VAVLPs as a preferred treatment modality.

Tables and figures

Table 1 Sociodemographic and clinical parameters of the participants (N=37)

Parameters	Frequency	Percentage
Age group		
21-29	6	16.2
30-39	8	21.6
40-49	10	27
50-59	7	18.9
60 and above	6	16.2

Sex		
Female	14	37.8
Male	23	62.2
Fracture class		
Class B	16	43.2
Class C	21	56.8
Comorbidities		
Hypertension	9	24.3
Diabetes mellitus	6	16.2
Osteoporosis	4	10.8
Smoking	5	13.5
Hypothyroidism	2	5.4

Table 2. Union time distribution (n=37)

Follow-up	Number of patients with union	Percentage
2 nd week	0	0
6 th week	12	32.4
10 th week	33	89.2
24 th week	37	100
Mean time to union (weeks)	11.8±2.3 weeks	

Table 3. Radiological outcome distribution (n=37)

Sarmiento's modification of Lindstrom	AO type B		AO type C		Total		p-value (Chi-square test)
	n	%	n	%	n	%	
Excellent	8	50	9	42.9	17	45.9	0.668
Good	6	37.5	10	47.6	16	43.3	
Fair	2	12.5	2	9.5	4	10.8	
Total	16	100	21	100	37	100	

Table 4. Functional outcome distribution (n=37)

Mayo wrist score	AO type B		AO type C		Total		p-value (Chisquare test)
	n	%	n	%	n	%	
Excellent (90-100)	10	62.5	8	38.1	18	48.6	0.323
Good (75-89)	5	31.2	10	47.6	15	40.5	
Fair (60-74)	1	6.3	3	14.3	4	10.9	
Total	16	100	21	100	37	100	

Table 5. Range of motion and grip strength at 12 months distribution (n=37)

Parameters	Mean	SD
Palmar flexion (o)	75	12
Dorsiflexion (o)	71	10
Supination (o)	82	8
Pronation (o)	80	9
Grip strength (kg)	28.5	5.1

*Multiple comorbidities possible in a single patient

Table 6. Complications at 12 months distribution (n=37)

Complication*	AO type B		AO type C		Total	
	Frequen- cy	Percent age	Frequen- cy	Percent age	Frequen- cy	Percent age
Stiffness of wrist	1	6.3	3	14.3	4	10.8
Malunion	0	0	1	4.8	1	2.7
Superficial infection	1	6.3	0	0	1	2.7
Broken implant	-	-	-	-	-	-

*Multiple complications possible in a single patient

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