

Functional and Radiological Outcomes of Distal Radius Fractures Treated with Volar Locking Plates: A Prospective Observational Study

¹Dr. Sahil Bhagat, Associate Professor, Department of Orthopaedics, NCR Institute of Medical Sciences, Meerut, Uttar Pradesh, India

²Dr. Pradeep Kumar Yadav, Assistant Professor, Department of Orthopaedics, Autonomous State Medical College & Allied Pt. Ram Prasad Bismil Hospital, Shahjahanpur, Uttar Pradesh, India

³Dr. Rahul Kumar Gupta, Associate Professor, Department of Orthopaedics, NCR Institute of Medical Sciences, Meerut, Uttar Pradesh, India

Corresponding Author: Dr. Rahul Kumar Gupta, Associate Professor, Department of Orthopaedics, NCR Institute of Medical Sciences, Meerut, Uttar Pradesh, India.

How to citation this article: Dr. Sahil Bhagat, Dr. Pradeep Kumar Yadav, Dr. Rahul Kumar Gupta, “Functional and Radiological Outcomes of Distal Radius Fractures Treated with Volar Locking Plates: A Prospective Observational Study”, IJMACR– September – 2026, Volume – 9, Issue – 5, P. No. 879 – 891.

Open Access Article: © 2026 Dr. Sahil Bhagat, et al. This is an open access journal and article distributed under the terms of the creative common’s attribution license (<http://creativecommons.org/licenses/by/4.0>). Which allows others to remix, tweak, and build upon the work non - commercially, as long as appropriate credit is given and the new creations are licensed under the identical terms.

Type of Publication: Original Research Article

Conflicts of Interest: Nil

Abstract

Introduction: Distal radius fractures are among the most frequently encountered fractures of the upper limb and may result in persistent pain, restricted wrist motion, reduced grip strength and functional disability, particularly when displacement or intra-articular involvement is present. Volar locking plate fixation permits stable internal fixation while facilitating early mobilisation and restoration of distal radial alignment. The present study evaluated functional recovery and radiological maintenance following volar locking plate fixation of distal radius fractures.

Aim: To evaluate the functional and radiological outcomes of distal radius fractures treated with volar locking plate fixation.

Methodology: This prospective observational study was conducted in the Department of Orthopaedics, NCR Institute of Medical Sciences, Meerut, Uttar Pradesh, India, from July 2025 to June 2026. Ninety-six adult patients with displaced or unstable distal radius fractures suitable for volar locking plate fixation were included. Functional outcome was assessed using the Disabilities of the Arm, Shoulder and Hand (DASH) score, wrist and forearm range of motion, and grip strength at 6 weeks, 3 months and 6 months. Radiological outcomes included radial height, radial inclination, volar tilt and ulnar

variance assessed immediately after surgery and at 6 months. Fracture union and postoperative complications were also recorded. Serial functional parameters were analysed using the Friedman repeated-measures test, radiological parameters using the paired t-test, and relationships between final radiological parameters and DASH scores using Spearman's rank correlation coefficient.

Result: The mean age was 47.6 ± 14.0 years and 60.4% of patients were female. Intra-articular fractures constituted 62.5% of cases. DASH scores improved from 32.44 ± 5.59 at 6 weeks to 16.95 ± 4.39 at 3 months and 7.21 ± 3.98 at 6 months ($p < 0.001$). Wrist flexion, extension, pronation, supination and grip strength also improved significantly over follow-up ($p < 0.001$ for each). At 6 months, radial height and volar tilt showed small but statistically significant changes, whereas radial inclination and ulnar variance remained relatively stable. Fracture union occurred in all patients by 16 weeks. Radial height showed a significant inverse correlation with final DASH score ($r = -0.36$, $p < 0.001$).

Conclusion: Volar locking plate fixation was associated with progressive functional recovery and satisfactory maintenance of distal radial alignment over six months. Restoration of radial height showed a significant relationship with final functional outcome.

Keywords: Distal Radius Fracture, Volar Locking Plate, DASH, Radiological Outcome, Functional Outcome.

Introduction

Distal radius fractures are among the most common fractures encountered in orthopaedic practice and represent an important cause of temporary and, in some patients, persistent upper-limb disability. Their clinical importance extends beyond fracture union because restoration of wrist anatomy and subsequent recovery of

motion, grip strength and hand function determine the patient's ability to return to routine activities and occupational demands. The distal radius contributes substantially to wrist biomechanics through its radial height, radial inclination, volar tilt and relationship with the ulna and carpus. Loss of these parameters following fracture may alter load transmission across the wrist and may contribute to pain, restricted movement, reduced grip strength and long-term functional impairment.

The pattern of distal radius fractures is heterogeneous. Some fractures are relatively stable and can be managed successfully with conservative treatment, whereas displaced, unstable or intra-articular fractures may require operative fixation to restore alignment and maintain reduction. Intra-articular involvement is particularly important because incongruity of the radiocarpal or distal radioulnar joint may adversely affect wrist mechanics. Patient age, bone quality, fracture configuration, displacement, articular involvement, functional demand and associated injuries all influence treatment selection. Consequently, the treatment of distal radius fractures has evolved from an emphasis on radiographic union alone towards restoration of anatomy and measurable functional recovery.

Volar locking plates have become widely used for operative fixation of unstable distal radius fractures. Their design provides angular stability through locking screws and allows fixation of distal fragments even when metaphyseal bone is comminuted or osteoporotic. The volar approach also permits direct restoration of the principal anatomical parameters of the distal radius. Stable fixation may facilitate earlier wrist mobilisation and rehabilitation, potentially reducing postoperative stiffness. However, successful fixation does not necessarily guarantee complete restoration of function,

and both radiological maintenance and patient-reported outcome measures remain important when evaluating treatment.

Several systematic reviews and meta-analyses have examined the role of volar locking plates in distal radius fractures. Oldrini et al. reported that volar locking plate fixation was associated with better early clinical and radiological outcomes compared with cast immobilisation, although differences in clinical outcomes became less pronounced at longer follow-up¹³. Li et al. similarly found improved DASH outcomes at several postoperative intervals and reported advantages in selected range-of-motion and radiological parameters following volar locking plate fixation compared with cast immobilisation⁵. These findings indicate that the potential advantage of operative fixation may be particularly evident during early functional recovery.

The relationship between radiological restoration and functional recovery has also received increasing attention. Bilal et al. evaluated radiological parameters after volar locking plate fixation and demonstrated that selected radiological measurements were associated with functional outcomes². Such observations are clinically relevant because successful fixation should not merely produce radiographic union but should preserve the anatomical parameters necessary for normal wrist mechanics. The degree to which each individual radiological parameter influences patient-reported disability, however, remains variable across studies.

The timing and magnitude of functional recovery following volar plate fixation are also important. Patients commonly experience considerable disability during the early postoperative period, followed by progressive improvement as fracture healing progresses and wrist mobilisation increases. DASH provides a patient-reported

measure of disability that allows this recovery to be quantified. Range of motion and grip strength provide complementary objective measures of recovery. Recent comparative evidence has shown that volar locking plate fixation may produce earlier functional improvement than some alternative methods, although long-term differences may be smaller.^{4,5}

Despite favourable functional outcomes, volar plating is associated with potential complications. Median nerve symptoms, tendon irritation, complex regional pain syndrome, infection, hardware-related symptoms, loss of reduction and subsequent implant removal have all been described. Nwosu et al., in a systematic review of randomised trials, reported an overall complication rate of 30.8%, with median nerve-related complications and hardware removal among the more frequent complications⁶. Pacchiarini et al. similarly demonstrated that complications and reinterventions remain relevant considerations following volar plate fixation⁷. These findings emphasise the importance of assessing safety alongside functional and radiological outcomes.

The evidence base also demonstrates that the apparent benefits of operative fixation depend on the comparison group and follow-up interval. Meta-analyses comparing volar locking plates with conservative treatment have shown early functional advantages but less pronounced differences at later follow-up^{5,13}. Similarly, comparisons with external fixation and Kirschner-wire fixation have demonstrated differences in early recovery and selected radiological parameters, but not uniform superiority across every outcome^{4,10,14}. Therefore, prospective assessment of patients treated with volar locking plates remains useful, particularly in regional tertiary-care populations where fracture characteristics, patient

demographics and rehabilitation practices may differ from those represented in international trials.

Indian clinical settings provide a particularly relevant context for such evaluation because patients may present with a mixture of low-energy falls and road-traffic injuries, with a broad age range and varying occupational demands. The proportion of intra-articular fractures and the ability to maintain reduction can influence functional recovery. A prospective study with standardised follow-up therefore provides an opportunity to document the trajectory of functional recovery and the stability of radiological restoration following volar locking plate fixation.

The present study was designed to evaluate the functional and radiological outcomes of distal radius fractures treated with volar locking plates in a tertiary-care orthopaedic setting. Functional recovery was assessed using DASH, wrist and forearm range of motion and grip strength at predefined postoperative intervals. Radiological restoration was assessed using radial height, radial inclination, volar tilt and ulnar variance, with comparison between immediate postoperative and six-month measurements. The study also examined the relationship between final radiological parameters and functional disability and documented postoperative complications during follow-up.

Aim

To evaluate the functional and radiological outcomes of distal radius fractures treated with volar locking plate fixation.

Materials and Methods

This prospective observational study was conducted in the Department of Orthopaedics, NCR Institute of Medical Sciences, Meerut, Uttar Pradesh, India, over a one-year period from July 2025 to June 2026. The study

included 96 adult patients presenting with acute displaced or unstable distal radius fractures considered suitable for operative fixation using a volar locking plate. Institutional Ethics Committee approval was obtained before commencement of the study, and written informed consent was obtained from all participants; the final manuscript should include the actual IEC approval/reference number before submission. Patients aged 18 years or above with acute displaced or unstable distal radius fractures requiring operative fixation, including both extra-articular and intra-articular fractures suitable for volar locking plate fixation, were eligible. Patients with pathological fractures, previous fracture or surgery involving the affected wrist, pre-existing significant wrist deformity or stiffness, neurological or musculoskeletal disorders affecting hand or wrist function, chronic inflammatory or significant degenerative wrist disease, associated major injuries of the same upper limb interfering with functional assessment, unwillingness to undergo operative treatment or follow-up, incomplete clinical or radiological records, or loss to follow-up before completion of the required assessment were excluded. Preoperative assessment included history regarding age, sex, occupation, hand dominance, affected side, mechanism of injury, time since injury and relevant comorbidities, together with examination of swelling, deformity, tenderness, skin condition, finger movements, distal vascular status and neurological function. Standard anteroposterior and lateral wrist radiographs were obtained, while computed tomography was performed selectively in complex intra-articular fractures when required for preoperative assessment and surgical planning. Fractures were categorized as intra-articular or extra-articular on preoperative radiographic assessment, and displacement,

comminution and articular involvement were documented. All patients underwent open reduction and internal fixation using a volar locking plate under appropriate regional or general anaesthesia through a standard volar approach. Reduction was performed with the objective of restoring radial height, radial inclination, volar tilt and articular alignment. The plate was fixed with locking and/or non-locking screws according to fracture configuration, and intraoperative fluoroscopy was used to assess reduction, plate position, screw placement and absence of significant intra-articular screw penetration. Postoperatively, patients were monitored for pain, swelling, wound condition and neurovascular status, and finger and elbow movements were encouraged. Wrist mobilisation was initiated according to fracture stability and fixation security, followed by progressive rehabilitation. Patients were assessed at 2 weeks, 6 weeks, 3 months and 6 months. The two-week visit was primarily used for wound, neurovascular and early postoperative assessment, whereas formal functional measurements were analysed at 6 weeks, 3 months and 6 months. Functional outcome was assessed using the Disabilities of the Arm, Shoulder and Hand (DASH) score, with lower scores indicating better functional status. Wrist flexion, extension, forearm pronation and supination were measured using a standard goniometer. Grip strength was assessed using a calibrated hand dynamometer and recorded in kilograms. Radiological assessment included radial height, radial inclination, volar tilt and ulnar variance on standard anteroposterior and lateral radiographs obtained immediately after surgery and during follow-up. Maintenance of reduction was assessed by comparing immediate postoperative measurements with six-month measurements. Fracture union was assessed clinically and radiologically, and time to union

was recorded in weeks. Postoperative complications including infection, median nerve symptoms, tendon irritation, wrist stiffness, complex regional pain syndrome, implant- or screw-related symptoms, secondary loss of reduction, delayed union, non-union and requirement for revision surgery or implant removal were documented. Complication categories were recorded separately and could overlap in an individual patient; therefore, their percentages were not intended to be summed. Serial functional parameters at 6 weeks, 3 months and 6 months were analysed using the Friedman repeated-measures test. Immediate postoperative and six-month radiological measurements were compared using the paired t-test. The relationship between six-month radiological parameters and the final DASH score was assessed using Spearman's rank correlation coefficient. Continuous variables were expressed as mean $\pm$ standard deviation and categorical variables as frequency and percentage. A p-value <0.05 was considered statistically significant. The primary study endpoint was six months after surgery, and the final assessment included DASH, range of motion, grip strength, fracture union, radiological parameters, maintenance of reduction and postoperative complications.

Time to union	n	%	Cumulative %
≤ 6 weeks	6	6.3	6.3
7–12 weeks	83	86.5	92.7
13–16 weeks	7	7.3	100.0
Non-union	0	0.0	100.0

Results

A total of 96 patients with distal radius fractures treated with volar locking plate fixation were included in the final analysis. The demographic and fracture characteristics demonstrated a mean age of 47.6 ± 14.0 years. Females constituted 60.4% of the study population and males 39.6%. The right wrist was involved in 53.1% and the left wrist in 46.9%. The most frequent mechanism of injury

was a fall on an outstretched hand, accounting for 57.3% of cases, followed by road-traffic accidents in 29.2% and falls from height in 13.5%. Intra-articular fractures were more frequent than extra-articular fractures, accounting for 62.5% and 37.5%, respectively.

Table 1: Baseline Demographic and Fracture Characteristics of the Study Population

Characteristic	Frequency (n=96)	Percentage (%)
Age, years		
Mean $\pm$ SD	47.6 $\pm$ 14.0	—
Sex		
Female	58	60.4
Male	38	39.6
Side involved		
Right	51	53.1
Left	45	46.9
Mechanism of injury		
Fall on outstretched hand	55	57.3
Road-traffic accident	28	29.2
Fall from height	13	13.5
Fracture pattern		
Intra-articular	60	62.5
Extra-articular	36	37.5

The above table illustrates that the study included 96 patients with a mean age of 47.6 ± 14.0 years. Females constituted the majority with 58 (60.4%) patients, while males accounted for 38 (39.6%). The right wrist was involved in 51 (53.1%) patients and the left wrist in 45 (46.9%). Fall on an outstretched hand was the commonest mechanism of injury, observed in 55 (57.3%) patients, followed by road-traffic accidents in 28 (29.2%) and falls from height in 13 (13.5%). Intra-articular fractures were

present in 60 (62.5%) patients, while 36 (37.5%) had extra-articular fractures.

Functional recovery demonstrated progressive improvement throughout follow-up. The mean DASH score decreased from 32.44 ± 5.59 at 6 weeks to 16.95 ± 4.39 at 3 months and 7.21 ± 3.98 at 6 months, indicating progressive reduction in disability. Wrist flexion increased from $42.17 \pm 6.94^\circ$ at 6 weeks to $65.76 \pm 5.24^\circ$ at 6 months, while extension increased from $41.39 \pm 7.21^\circ$ to $63.58 \pm 5.62^\circ$. Pronation and supination also improved progressively. Grip strength increased from 13.14 ± 4.38 kg at 6 weeks to 23.96 ± 3.96 kg at 6 months. The changes in all functional parameters across follow-up were statistically significant.

Table 2: Serial Functional Outcomes Following Volar Locking Plate Fixation

Functional parameter	6 weeks	3 months	6 months	p-value
DASH score	32.44 $\pm$ 5.59	16.95 $\pm$ 4.39	7.21 $\pm$ 3.98	<0.001
Wrist flexion ($^\circ$)	42.17 $\pm$ 6.94	53.77 $\pm$ 6.25	65.76 $\pm$ 5.24	<0.001
Wrist extension ($^\circ$)	41.39 $\pm$ 7.21	52.83 $\pm$ 6.41	63.58 $\pm$ 5.62	<0.001
Forearm pronation ($^\circ$)	64.19 $\pm$ 6.34	72.61 $\pm$ 4.73	78.83 $\pm$ 3.51	<0.001
Forearm supination ($^\circ$)	61.40 $\pm$ 7.13	70.65 $\pm$ 5.12	77.76 $\pm$ 3.95	<0.001
Grip strength (kg)	13.14 $\pm$ 4.38	18.54 $\pm$ 4.29	23.96 $\pm$ 3.96	<0.001

Friedman repeated-measures test.

The above table illustrates progressive improvement in functional parameters following volar locking plate fixation. The mean DASH score decreased from 32.44 ± 5.59 at 6 weeks to 16.95 ± 4.39 at 3 months and $7.21 \pm$

3.98 at 6 months. Wrist flexion, extension, pronation and supination increased progressively during follow-up. Grip strength also increased from 13.14 ± 4.38 kg at 6 weeks to 23.96 ± 3.96 kg at 6 months. The changes observed in all functional parameters across the three follow-up assessments were statistically significant ($p < 0.001$).

Radiological assessment demonstrated maintenance of the principal parameters of distal radial alignment. Mean radial height changed from 11.30 ± 1.29 mm immediately after surgery to 11.12 ± 1.21 mm at 6 months, representing a mean change of -0.18 ± 0.62 mm ($p = 0.005$). Radial inclination changed from $22.48 \pm 2.71^\circ$ to $22.28 \pm 2.41^\circ$ and this change was not statistically significant ($p = 0.053$). Volar tilt changed from $8.80 \pm 3.46^\circ$ to $8.41 \pm 3.20^\circ$, with a statistically significant mean change of $-0.39 \pm 1.31^\circ$ ($p = 0.004$). Ulnar variance changed from 0.18 ± 0.86 mm to 0.26 ± 0.73 mm, without a statistically significant difference ($p = 0.071$). All 96 fractures united during follow-up, with the majority achieving union between 7 and 12 weeks.

Table 3: Radiological Outcomes and Time to Fracture Union

Radiological parameter	Immediate postoperative	6 months	Mean change	p-value
Radial height (mm)	11.30 ± 1.29	11.12 ± 1.21	-0.18 ± 0.62	0.005
Radial inclination ($^\circ$)	22.48 ± 2.71	22.28 ± 2.41	-0.20 ± 1.00	0.053
Volar tilt ($^\circ$)	8.80 ± 3.46	8.41 ± 3.20	-0.39 ± 1.31	0.004
Ulnar variance (mm)	0.18 ± 0.86	0.26 ± 0.73	$+0.08 \pm 0.43$	0.071

Paired t-test for radiological parameters.

The above table illustrates that the principal radiological parameters were largely maintained following volar locking plate fixation. Radial height showed a small reduction from 11.30 ± 1.29 mm immediately postoperatively to 11.12 ± 1.21 mm at 6 months, while volar tilt showed a small reduction from $8.80 \pm 3.46^\circ$ to $8.41 \pm 3.20^\circ$. Changes in radial inclination and ulnar variance were not statistically significant. Regarding fracture union, 6 (6.3%) patients achieved union within 6 weeks, 83 (86.5%) between 7 and 12 weeks and 7 (7.3%) between 13 and 16 weeks. No non-union was observed. At six months, radial height demonstrated a moderate inverse relationship with DASH score, with higher radial height associated with lower disability scores (Spearman $\rho = -0.36$, $p < 0.001$). Radial inclination also showed a weak inverse correlation with DASH score ($\rho = -0.23$, $p = 0.026$). The relationships between volar tilt and DASH and between ulnar variance and DASH were not statistically significant. The most frequently documented complication was wrist stiffness in 9 (9.4%) patients, followed by transient median nerve symptoms in 5 (5.2%). Complication categories were not mutually exclusive.

Table 4: Correlation of Radiological Parameters with Six-Month DASH Score and Postoperative Complications

A. Correlation of Radiological Parameters with Six-Month DASH Score

Radiological parameter	Spearman's ρ with 6-month DASH	p-value
Radial height	-0.36	<0.001
Radial inclination	-0.23	0.026
Volar tilt	-0.14	0.172
Ulnar variance	+0.05	0.661

Complication	n	%
Wrist stiffness	9	9.4
Transient median nerve symptoms	5	5.2
Superficial surgical-site infection	3	3.1
Tendon irritation	3	3.1
Complex regional pain syndrome	2	2.1
Implant/screw-related symptoms	2	2.1
Secondary loss of reduction	2	2.1
Revision surgery/implant removal	1	1.0

Complication categories could overlap and therefore percentages should not be summed.

The above table illustrates that radial height had a statistically significant inverse correlation with the six-month DASH score ($\rho=-0.36$, $p<0.001$), while radial inclination showed a weaker but statistically significant inverse correlation ($\rho=-0.23$, $p=0.026$). No statistically significant correlation was observed between volar tilt and DASH score or between ulnar variance and DASH score. Among postoperative complications, wrist stiffness was most frequently documented in 9 (9.4%) patients, followed by transient median nerve symptoms in 5 (5.2%), superficial surgical-site infection in 3 (3.1%) and tendon irritation in 3 (3.1%). Complex regional pain syndrome, implant/screw-related symptoms and secondary loss of reduction occurred in 2 (2.1%) patients each, while revision surgery or implant removal was required in 1 (1.0%) patient.

Discussion

The present prospective observational study evaluated 96 patients with distal radius fractures treated using volar locking plate fixation and demonstrated progressive improvement in patient-reported function, wrist and forearm motion and grip strength over six months, together with maintenance of the principal radiological parameters of distal radial alignment. The mean DASH

score decreased from 32.44 at six weeks to 7.21 at six months, while wrist flexion, extension, pronation, supination and grip strength increased progressively. Radiologically, only small changes in radial height and volar tilt were observed over six months, and no non-union occurred. Radial height showed the largest absolute correlation coefficient with the final DASH score among the radiological parameters assessed. These findings describe the functional and radiological course observed in this cohort following volar locking plate fixation and are broadly consistent with published prospective studies of patients treated with this fixation method.

The most important functional finding was the progressive reduction in DASH score from 32.44 ± 5.59 at six weeks to 16.95 ± 4.39 at three months and 7.21 ± 3.98 at six months. The overall change was statistically significant. This pattern indicates that substantial functional recovery continued beyond the early postoperative period. Li et al., in a systematic review and meta-analysis of randomised controlled trials, reported differences in DASH outcomes between volar locking plates and cast immobilisation at several follow-up points⁵. Oldrini et al. similarly reported differences in early functional outcomes between volar locking plate fixation and cast immobilisation, with smaller differences at longer follow-up¹³. The progressive improvement observed in the present cohort is therefore compatible with the broader literature describing recovery following distal radius fracture fixation, although the present single-arm study cannot determine whether the observed recovery was greater than that achieved with alternative treatments.

The magnitude of improvement in the present study is also compatible with the prospective findings of Mohankumar et al., who evaluated functional and

radiological outcomes following volar locking plate fixation¹. Direct numerical comparison should be interpreted cautiously because follow-up protocols, fracture severity and baseline patient characteristics differ between cohorts. Nevertheless, both studies demonstrated improvement in patient-reported function following treatment with volar locking plates. The present study additionally demonstrated a serial trajectory, with DASH decreasing at each assessment from six weeks through six months. This longitudinal pattern indicates continued recovery during the postoperative period, although improvement cannot be attributed to the fixation method alone because fracture healing, rehabilitation and the natural course of recovery may all contribute.

Range of motion demonstrated a similar progressive pattern. Mean flexion increased from 42.17° at six weeks to 65.76° at six months, while extension increased from 41.39° to 63.58°. Pronation and supination also improved significantly. Li et al. reported differences in wrist range of motion at selected postoperative intervals between patients treated with volar locking plates and those treated with cast immobilisation⁵. The findings of the present study are also compatible with the prospective clinical outcomes reported by Mohankumar et al.¹. The gradual improvement in motion may reflect the combined effects of fracture stabilisation, healing, rehabilitation and progressive use of the wrist. The present data do not establish that the plate itself independently caused the observed functional recovery.

Grip strength increased from 13.14 ± 4.38 kg at six weeks to 23.96 ± 3.96 kg at six months. Grip strength provides an objective complement to DASH because patient-reported disability and measured strength assess related but distinct aspects of recovery. The increase observed in the present cohort is consistent with reports of progressive

recovery of grip strength following treatment of distal radius fractures with volar locking plates. Li et al. reported differences in clinical outcomes in selected comparisons of volar locking plates with cast treatment⁵. Zahed et al. also reported differences in grip strength at several postoperative intervals in their systematic review and meta-analysis comparing volar locking plates with external fixation⁵. The present study demonstrates a similar direction of recovery within a single-treatment prospective cohort; however, it does not permit direct estimation of the relative effect of volar locking plate fixation compared with another treatment.

Radiological outcomes demonstrated that the principal parameters of distal radial alignment were largely maintained during follow-up. Radial height decreased by only 0.18 mm over six months, while radial inclination decreased by 0.20°. Volar tilt decreased by 0.39°, and ulnar variance increased by 0.08 mm. Although the changes in radial height and volar tilt reached statistical significance, their absolute magnitudes were small. Statistical significance should therefore be distinguished from clinical significance. The observed measurements indicate that the radiological alignment recorded immediately after fixation was largely maintained during the six-month follow-up period.

Bilal et al. specifically examined the association between radiological parameters and functional outcomes after distal radius fracture fixation with volar locking plates and demonstrated relationships between selected radiological measurements and postoperative function². The present study similarly found significant correlations between radial height, radial inclination and final DASH score, whereas volar tilt and ulnar variance did not show statistically significant relationships with DASH. These findings indicate that individual radiological parameters

may have different strengths of association with patient-reported disability. Because the present analysis was observational and unadjusted, these associations should not be interpreted as evidence that changes in a particular radiological parameter directly caused functional differences.

The findings regarding fracture union were favourable within the observed follow-up period. Six patients achieved union by six weeks, 83 between seven and 12 weeks and seven between 13 and 16 weeks, with no non-union. Mohankumar et al. reported favourable radiological outcomes following volar locking plate fixation¹. Systematic reviews have also described low rates of non-union and malunion following volar plate fixation^{6,7}. The absence of non-union in the present cohort is compatible with these published observations. Nevertheless, the sample size of 96 and six-month follow-up limit the ability of the study to detect uncommon late complications or delayed adverse outcomes.

The correlation analysis provided an additional observation within the present cohort. Radial height demonstrated a moderate inverse correlation with DASH ($\rho=-0.36$, $p<0.001$), indicating that patients with greater maintained radial height tended to have lower disability scores at six months. Radial inclination showed a weaker inverse relationship ($\rho=-0.23$, $p=0.026$). In contrast, volar tilt and ulnar variance were not significantly correlated with DASH. Bilal et al. similarly investigated relationships between radiological parameters and functional outcome following volar locking plate fixation². The present findings therefore demonstrate an association between selected radiological measurements and functional status in this cohort. They do not establish that preservation of radial height or radial inclination independently determines functional recovery.

The complication profile in the present study included wrist stiffness in 9.4%, transient median nerve symptoms in 5.2%, superficial surgical-site infection and tendon irritation in 3.1% each, complex regional pain syndrome and implant/screw-related symptoms in 2.1% each, and revision surgery or implant removal in 1.0%. These categories should not be summed because individual patients could have experienced more than one complication. Nwosu et al. reported an overall complication rate of 30.8% following volar locking plate fixation in randomised controlled trials, with median nerve-related complications, hardware removal and tenosynovitis among the reported complications⁶. Pacchiarini et al. similarly identified nerve, tendon and hardware-related events among complications reported after volar plate fixation⁷. Direct comparison of the present individual complication frequencies with aggregate rates from systematic reviews is limited by differences in definitions, surveillance periods, patient populations and reporting methods. The present study therefore documents the complication pattern observed in its own cohort rather than establishing a lower or higher overall complication risk.

Jiang and Day have also described differences in complication profiles between volar and dorsal plate constructs⁸. The relatively low frequency of tendon irritation observed in the present cohort may be noted in relation to these published findings; however, the present observational design does not permit attribution of this finding to the volar approach or to plate positioning. Similarly, the low frequency of implant removal in the present cohort should be interpreted as an observation during the six-month follow-up period and should not be taken to indicate that implant removal is generally unnecessary. Hardware removal rates may vary according

to patient characteristics, implant-related symptoms, surgeon preference and clinical indications^{6,7}.

The present findings should also be interpreted alongside comparative evidence. Tariq et al. and Gou et al. evaluated outcomes of volar locking plates against other fixation modalities, including Kirschner-wire fixation and external fixation, respectively^{10,14}. Zahed et al. also compared volar locking plates with external fixation and reported differences in selected early functional outcomes¹⁴. These comparative studies provide context for interpreting the present findings but cannot be used to establish comparative treatment effects within the current cohort. The present study was designed to document the functional, radiological and complication profile of patients treated with volar locking plate fixation and did not include a concurrent control group.

Similarly, the JBJS Review examined volar locking plate fixation versus closed reduction in adults and reported that differences in patient-reported function between treatment groups may become smaller at longer follow-up¹⁵. This evidence provides useful context for the six-month findings of the present study. However, the substantial improvement in DASH observed in the current cohort should be interpreted as recovery over time among patients receiving volar locking plate fixation rather than as evidence of superiority over alternative treatments. Such a distinction is important when findings from a single-arm observational cohort are considered alongside randomised controlled trials.

The study has several strengths. It was prospective, used a clearly defined treatment cohort and included serial functional assessments at three clinically relevant postoperative intervals. The study combined patient-reported function, objective range of motion, grip strength, radiological measurements, fracture union and

complications rather than relying on a single outcome. The correlation analysis also provided information regarding the relationship between anatomical measurements and final functional disability. The standardised six-month endpoint allowed the final results to be interpreted consistently across the cohort.

Several limitations should nevertheless be acknowledged. First, this was a single-centre observational study with a relatively modest sample size of 96 patients, which limits generalisability. Second, there was no non-operative or alternative fixation control group; therefore, the study cannot determine comparative effectiveness or establish superiority of volar locking plate fixation over other treatment strategies. Third, follow-up was limited to six months and may not capture late post-traumatic arthritis, delayed tendon complications or later implant removal. Fourth, although the study evaluated intra-articular versus extra-articular involvement, a detailed AO/OTA or other formal fracture classification was not incorporated into the reported analysis. Fifth, the study did not include a formal multivariable analysis adjusting for age, fracture pattern, mechanism or other potential confounders. Finally, correlation between radiological measurements and DASH does not establish causality. These limitations should be considered when interpreting the findings and extrapolating them to other populations.

Conclusion

In this prospective cohort of 96 patients with distal radius fractures treated with volar locking plate fixation, progressive improvement was observed in DASH score, wrist and forearm range of motion and grip strength over six months. The principal radiological parameters of distal radial alignment were largely maintained during follow-up, and all fractures achieved union by 16 weeks. Radial height demonstrated a significant inverse

association with the six-month DASH score, indicating that greater maintained radial height was associated with lower patient-reported disability within this cohort. Overall, the study documents favourable functional recovery, maintenance of radiological alignment and fracture union following volar locking plate fixation; however, because there was no control group, these findings should be interpreted as outcomes observed after this treatment rather than evidence of comparative efficacy or superiority over alternative treatment methods.

Declarations

Ethics Approval: Approved by the Institutional Ethics Committee of NCR Medical College, Meerut, Uttar Pradesh, India.

Informed Consent: Written informed consent was obtained from all participants.

Data Availability: The study data are available from the corresponding author on reasonable request, subject to institutional and ethical requirements.

Author Contributions: To be completed according to the actual contributions of all authors.

References

1. Mohankumar M, Murugesan T, Balamurugan P, Venkadesh A, Vishal M, Muralikrishnan R. Functional and radiological outcomes following volar locking plate fixation for distal radius fractures: a prospective analytical study. *J Orthop Case Rep.* 2025;15(12):421-429. doi:10.13107/jocr.2025.v15.i12.6578.
2. Bilal RS, Rizwan HR, Marij Z, Pervaiz MH, Haroon R. Association of radiological parameters to functional outcomes after distal radius fracture fixation with volar locking plate: a prospective cohort study. *Malays Orthop J.* 2025;19(3):122-129. doi:10.5704/MOJ.2511.016.
3. Nasir AS, Memon K, Mersal M, Kashani A, Fatima T, Ajnin S, et al. Radiological and functional outcomes following distal radius fixation with a volar locking plate. *Cureus.* 2025;17(9):e91422. doi:10.7759/cureus.91422.
4. Zahed M, Elmesalmi M, El Menawy Z, Elnaggar N, Ahmed F, Odeh M, et al. Volar locking plate versus external fixation for distal radius fractures: a systematic review and meta-analysis of randomized controlled trials. *Cureus.* 2026;18(1):e100789. doi:10.7759/cureus.100789.
5. Li F, Tan Y, Cui L, Tian L. Efficacy and safety of volar locking plate versus cast immobilization for distal radius fractures: a systematic review and meta-analysis of randomized controlled trials. *J Plast Surg Hand Surg.* 2024;59: 108-116. doi:10.2340/jphs.v59.41372.
6. Nwosu C, Rodriguez K, Zeng S, Klifto KM, Klifto CS, Ruch DS. Complications following volar locking plate fixation of distal radius fractures in adults: a systematic review of randomized control trials. *J Hand Surg Am.* 2023;48(9):861-874. doi:10.1016/j.jhssa.2023.04.022.
7. Pacchiarini L, Oldrini LM, Feltri P, Lucchina S, et al. Complications after volar plate synthesis for distal radius fractures. *EFORT Open Rev.* 2024;9(6):567-580. doi:10.1530/EOR-23-0188.
8. Jiang EX, Day CS. Complications of volar versus low-profile dorsal plating of distal radius fractures. *J Am Acad Orthop Surg.* 2025;33(17):971-976. doi:10.5435/JAAOS-D-23-01169.
9. Latypov N, Golubev I, Borisova A. Volar locking plate versus closed reduction and immobilization for

- distal radius fracture in the elderly: systematic review and meta-analysis of randomized controlled trials. *J Wrist Surg.* 2024;13(6):559-571. doi:10.1055/s-0043-1774331.
10. Tariq MA, Ali U, Uddin QS, Altaf Z, Mohiuddin A. Comparison between volar locking plate and Kirschner wire fixation for unstable distal radius fracture: a meta-analysis of randomized controlled trials. *J Wrist Surg.* 2024;13(5):469-480. doi:10.1055/s-0043-1768235.
11. Pérez-Úbeda MJ, Arribas P, Gimeno García-Andrade MD, Garvín L, Rodríguez A, Ponz V, et al. Adjuvant arthroscopy does not improve the functional outcome of volar locking plate for distal radius fractures: a randomized clinical trial. *Arthroscopy.* 2024;40(2): 305-317. doi:10.1016/j.arthro. 2023.06.036.
12. Sastya AS, Mishra A, Parihar YS. A comparative study of functional outcomes between conservative management and volar locking plate fixation in extra-articular distal radius fractures. *Cureus.* 2025;17(11):e96496. doi:10.7759/cureus.96496.
13. Oldrini LM, Feltri P, Lucchina S, et al. Volar locking plate versus cast immobilization for distal radius fractures: a systematic review and meta-analysis. *Eur J Orthop Surg Traumatol.* 2022;32: 1245-1258. doi:10.1530/EOR-22-0022.
14. Gou Q, Xiong X, Cao D, He Y, Li X. Volar locking plate versus external fixation for unstable distal radius fractures: a systematic review and meta-analysis based on randomized controlled trials. *BMC Musculoskelet Disord.* 2021;22: 433. doi:10.1186/s12891-021-04289-7.
15. Volar locking plate fixation versus closed reduction for distal radial fractures in adults: a systematic review and meta-analysis. *JBJS Rev.* 2021;9(1): e20.00022. doi: 10.2106/ JBJS.RVW.20.00022.