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Original Article

Orthopaedics Section

Management of Distal Radius Fractures Using Volar Locked Compression Plates: Functional and Radiological Outcomes with a Ten-year Follow-up

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ABSTRACT

Introduction: Distal Radius Fractures (DRFs) are among the most common fractures of the upper extremity, with varying degrees of instability that significantly influence treatment outcomes. The management of unstable DRFs has evolved with the introduction of volar Locked Compression Plates (LCPs), allowing stable fixation and early rehabilitation.

Aim: To evaluate the functional and radiological outcomes of unstable DRFs managed with open reduction and internal fixation using LCPs.

Materials and Methods: This prospective study included 25 adult patients with unstable DRFs presenting within 14 days of injury. All patients underwent open reduction and internal fixation using volar LCPs. Fractures were classified preoperatively according to the Fernandez classification. Radiological assessment was performed at 3, 6, and 12 months to evaluate fracture union and restoration of anatomical parameters. Wrist range of motion was measured using goniometry. Functional outcomes were assessed using the Disabilities of the Arm, Shoulder, and Hand (DASH) questionnaire at six weeks, three months, six months, one year, and annually up to 10 years. Statistical analysis was performed using paired t-tests, with a p-value <0.05 considered statistically significant.

Results: All surgical wounds healed primarily without major complications. Twenty-three fractures achieved union within three months, while two cases showed delayed union by six months. Transient median nerve symptoms were observed in two patients and resolved with conservative management. Radiological parameters demonstrated significant improvement postoperatively and were maintained throughout follow-up. Functional outcomes showed progressive improvement, with a mean DASH score of 6.85 at one year and 1.28 at ten years, which was statistically significant (p<0.001).

Conclusion: Volar LCP fixation for unstable DRFs provides stable fixation, facilitates early mobilisation, and results in excellent long-term functional and radiological outcomes with minimal complications.

Keywords: Disabilities of the arm, shoulder and hand score, Goniometry, Open reduction internal fixation

INTRODUCTION

The DRFs are among the most frequently encountered fractures managed by trauma and Orthopaedic surgeons, accounting for approximately 17.5% of all fractures involving the upper extremity [1]. These fractures commonly occur around the wrist joint and demonstrate a bimodal age distribution, presenting as low-energy injuries in the elderly population and as high-energy trauma in younger individuals [2]. Depending on the mechanism of injury and fracture configuration, DRFs may be classified as Colles', Smith's, or Barton's fractures [3].

Several factors have contributed to the increasing incidence of DRFs, including changes in lifestyle, environmental influences, increased life expectancy, childhood obesity, osteoporosis in the elderly, and a rising incidence of high-energy trauma involving the wrist [4]. Epidemiological studies have shown a higher prevalence of DRFs in postmenopausal women and paediatric males; however, a consistently high incidence has also been reported among young adult males aged 19-49 years [3,5].

The primary objective in the management of DRFs is to achieve accurate anatomical reduction and maintain it until fracture union. This is particularly challenging in unstable fractures, where loss of reduction is common if adequate fixation is not achieved. Treatment modalities for DRFs range from conservative methods such as elastic bandaging and casting to more complex surgical interventions, including percutaneous pinning, external fixation, and open reduction with internal fixation. The choice of treatment depends on fracture pattern, degree of instability, and patient-related factors, and remains a subject of ongoing debate.

Over the past two decades, there has been a significant shift in the management of unstable DRFs, with an increasing trend toward surgical fixation. This change has been accompanied by a decline in percutaneous fixation techniques and an increased use of volar locking plate systems [6,7]. Volar fixed-angle locking plates have gained widespread acceptance due to their ability to provide stable fixation, maintain fracture reduction over time, and allow early postoperative mobilisation, thereby minimising the risk of secondary displacement [8].

Despite the growing use of volar LCPs in the management of unstable DRFs, limited literature is available evaluating their long-term functional outcomes using standardised scoring systems. In this context, the present study was undertaken to assess the functional and radiological outcomes of unstable DRFs treated with volar LCPs.

MATERIALS AND METHODS

This prospective study was conducted from 1 August, 2009 to 1 August, 2021 (10 years follow-up) in the Department of Orthopaedics at the Delhi Institute of Trauma and Orthopaedics, Sant Parmanand Hospital, New Delhi, India (Registration No. PR/DLSPH/09100ORT3). The study included 25 consecutive patients who presented to the outpatient department or emergency services with unstable DRFs. All patients were explained in detail about the nature of the fracture and the proposed management

using LCPs, and informed written consent was obtained prior to inclusion.

Inclusion and Exclusion criteria: Patients of either gender aged more than 18 years with fresh unstable DRFs less than 14-day-old were included in the study. Fractures associated with active infection, open injuries, fractures older than 14 days, associated periarticular fractures involving the shoulder, elbow, or fingers, and degloving injuries of the hand were excluded.

Study Procedure

A detailed proforma documenting clinical history, mechanism of injury, and physical examination findings was completed in both preoperative and postoperative periods. Baseline radiographs and functional scores were recorded prior to surgical intervention. All fractures were classified preoperatively according to the Fernandez classification system [9].

Fractures were considered unstable based on predefined criteria, which included radial angulation greater than 10°, axial radial shortening exceeding 5 mm, articular incongruity or step-off greater than 2 mm, comminution of one cortex extending across the mid-axial line on lateral radiographs, comminution of both dorsal and palmar cortices, or fractures deemed irreducible [10,11]. All patients underwent surgery following complete medical evaluation and pre-anaesthetic assessment. Anaesthesia was administered in the form of either a brachial plexus block or general anaesthesia, as determined by the anaesthetist. A wide pneumatic tourniquet was applied, and the operative limb was prepared and draped under strict aseptic precautions. Intraoperative fluoroscopic guidance using an image intensifier was employed in all cases.

The fractures were exposed using the standard volar Henry approach to the distal radius [11,12]. The distal and radial borders of the pronator quadratus muscle were elevated and retracted ulnarly to expose the fracture site, thereby creating access to the space beneath the flexor tendons (Parona's space). Open reduction was achieved using intrafocal leverage techniques with the application of mild traction. In cases of extreme instability, temporary Kirschner wires were used to maintain the reduced articular surface; this was required in five cases, while the remaining fractures were reduced without temporary K-wire fixation. LCPs of 2.4 mm and 3.5 mm sizes were used depending on the fracture pattern and degree of comminution. A 3.5 mm LCP was used in 12 patients with increased comminution, a 2.4 mm LCP in 12 patients, and a variable-angle 2.4 mm LCP in one patient.

After achieving satisfactory reduction under direct vision and fluoroscopic confirmation, the plate was fixed using appropriately sized locking screws placed both distal and proximal to the fracture site. Reduction accuracy, plate stability, and wrist range of motion were assessed intraoperatively. Wounds were closed in layers, and sterile antiseptic dressings were applied. Postoperative anteroposterior and lateral radiographs of the operated wrist were obtained. Intravenous antibiotics were administered until the third postoperative day or until discharge. A removable wrist brace was provided for support for four weeks. Patients were reviewed in the outpatient department on the 14th postoperative day for suture removal and initial assessment, followed by subsequent follow-ups at four weeks, six weeks, three months, six months, and one year.

Clinical evaluation during follow-up included assessment of fracture healing, time to union, median nerve involvement, infection, and other complications. Wrist range of motion, including flexion-extension and radioulnar deviation, was measured using a goniometer, while forearm pronation and supination were assessed with the elbow flexed to 90° at the patient's side. Radiological assessment was performed at three months, six months, and one year to evaluate fracture union, radial inclination, radial shortening, and volar tilt. After completion of one year of follow-up, annual telephonic assessments were conducted for up to ten years to obtain long-term functional feedback, including DASH questionnaire responses, persistence of symptoms, activity levels, and any late complications.

Functional outcomes were assessed using the DASH questionnaire at six weeks, three months, six months, one year, and ten years postoperatively. DASH scores were graded as excellent (0-15), good (16-35), fair (36-50), and poor (>50).

STATISTICAL ANALYSIS

All data were compiled using a standardised proforma, and mean values of quantitative variables at different follow-up intervals were compared using paired t-tests. A p-value of less than 0.05 was considered statistically significant. Statistical analysis was performed using the Statistical Package for Social Sciences (SPSS) version 25.0.

RESULTS

The study included 25 patients with unstable DRFs who were treated with open reduction and internal fixation using volar LCPs and followed-up for a minimum of one year, with annual telephonic follow-up extending up to ten years, during which all 25 patients were successfully contacted. The results were analysed in terms of demographic characteristics, mode of injury, radiological restoration, fracture union, functional recovery, and complications.

The distribution of patients according to age groups and mode of injury is summarised in [Table/Fig-1]. Road traffic accidents were the most common mechanism of injury across all age groups, particularly in patients between 30 and 50 years of age. Falls were more commonly observed in older age groups. This distribution reflects the predominance of high-energy trauma in the economically active age group. As per the present study, Type II consisted of maximum number of fractures 8 (32%), followed by Type III and Type IV, 6 (24)% in each group. There were 3 (12%) patients in Type I and the least in Type V, 2 (8%) patients [Table/Fig-2].

Age group	Mode of injury	
	RTA	Falls
<30 years	3 (12%)	1 (4%)
30-50 years	11 (44%)	5 (20%)
>50 years	4 (16%)	1 (4%)

[Table/Fig-1]: Distribution of patients according to age groups and mode of injury.

Fernandez	AO equivalent	No. of Patients (%)
Type I	23A	3 (12%)
Type II	23B	8 (32%)
Type III	23C	6 (24%)
Type IV	23C	6 (24%)
Type V	23C	2 (8%)
Total		**25 (100%)**

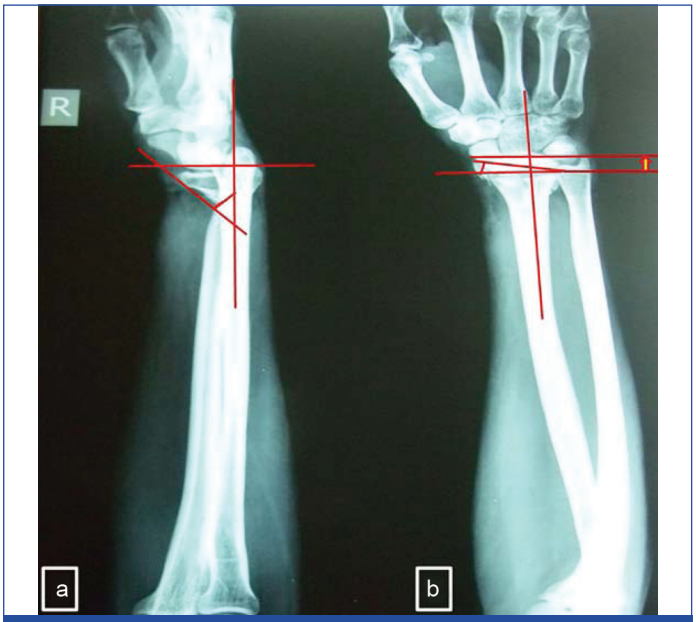
[Table/Fig-2]: Fernandez Fracture Classification with along AO equivalent.

Radiological assessment focused on radial tilt, radial inclination, and radial length to evaluate the adequacy of fracture reduction and maintenance of anatomical alignment. [Table/Fig-3] compares the mean preoperative and postoperative values of these parameters. A marked improvement was observed in all radiological parameters following surgical fixation. Postoperative values approached normal anatomical standards and were maintained during follow-up, indicating effective restoration and stability of fracture alignment.

Radial tilt°		Radial inclination°		Radial length (mm) †	
Pre-op	Post-op	Pre-op	Post-op	Pre-op	Post-op
7.40±6.08	9.88±0.73	6.52±4.69	20.60±1.22	2.84±1.62	10.36±0.95

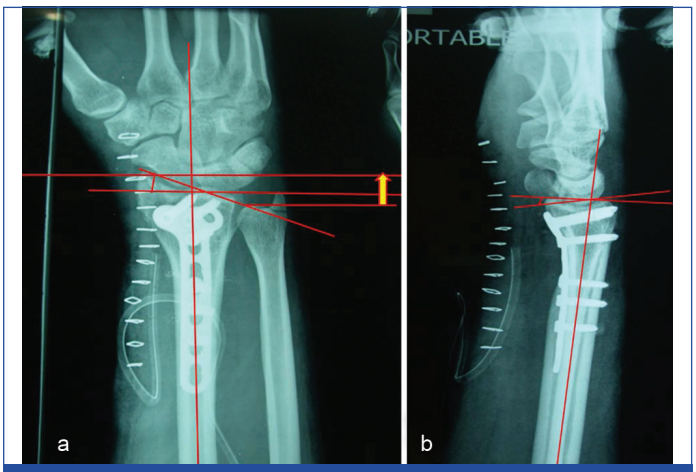
[Table/Fig-3]: Comparison of mean preoperative and postoperative radiological parameters of the distal radius.
Pre-op: preoperative; post-op: postoperative; 11 degrees of radial tilt is average; 23 mm of radial inclination is average; 11 mm of axial length is average

Representative preoperative radiographs illustrating the severity of deformity are shown in [Table/Fig-4]. The lateral view demonstrates complete loss of normal volar tilt with displacement of the distal fragment relative to the radial shaft, while the anteroposterior view shows marked reduction in radial inclination and radial height compared to normal anatomical values. These findings highlight the unstable nature of the fractures included in the study.



[Table/Fig-4]: Preoperative radiographs of an unstable Distal Radius Fracture (DRF): (a) Lateral view showing complete loss of normal volar (palmar) tilt with displacement of the distal fracture fragment in relation to the perpendicular axis of the radial shaft (volar tilt reduced to 0° instead of the normal 12°); (b) Anteroposterior view demonstrating marked reduction in radial inclination (5° instead of the normal 23°) and decreased radial length/radial height (5 mm instead of the normal 11 mm), as indicated by the yellow arrows.

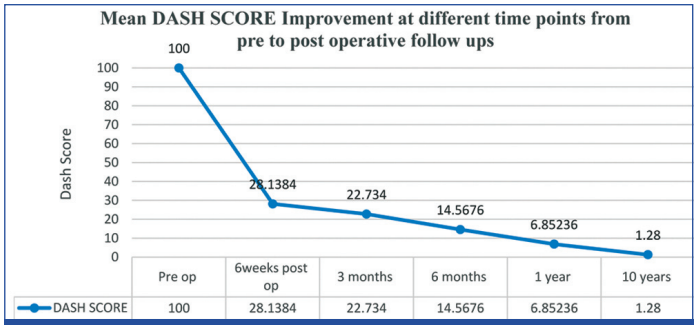
Postoperative radiographs shown in [Table/Fig-5] demonstrate successful restoration of anatomical parameters following fixation with volar LCPs. Normal radial inclination, radial height, and volar tilt were achieved and maintained, confirming the effectiveness of the surgical technique in achieving stable anatomical reduction.



[Table/Fig-5]: Postoperative radiographs demonstrating anatomical restoration following volar Locked Compression Plate (LCP) fixation: (a) Anteroposterior view showing restoration of normal radial inclination (23°) and radial length/radial height (11 mm), indicated by the yellow arrows; (b) Lateral view demonstrating complete restoration of normal volar (palmar) tilt to approximately 12°.

Functional recovery was assessed using the DASH questionnaire at predefined intervals. A progressive reduction in mean DASH scores was observed from the early postoperative period to long-term follow-up, as illustrated in [Table/Fig-6]. This trend indicates continuous functional improvement with time following surgical fixation.

Analysis of Variance (ANOVA) was performed to assess differences in mean DASH scores at different follow-up intervals, as shown in [Table/Fig-7]. The F-value was significantly higher than the critical value, with a p-value of less than 0.001, indicating a statistically significant improvement in functional outcomes across all follow-up periods.

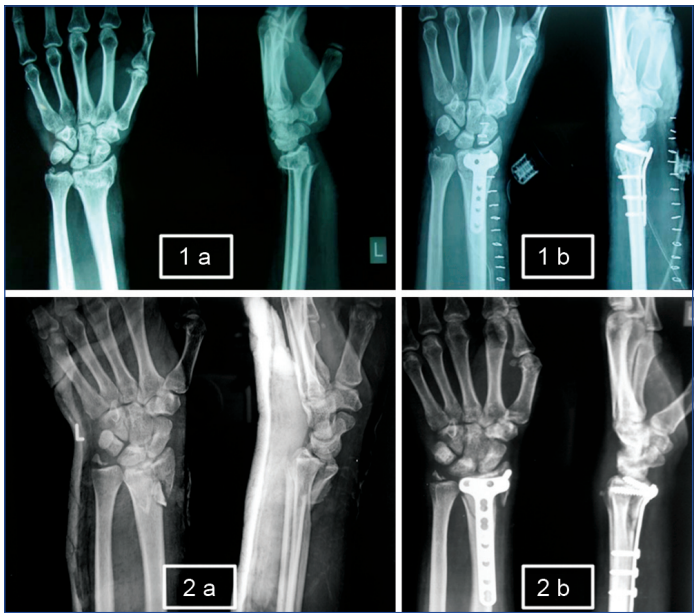


[Table/Fig-6]: Graph showing progressive improvement in mean DASH scores at different follow-up intervals from preoperative status to long-term postoperative follow-up.

DASH score follow-up	Mean	SD	F	F critical value	p-value
6 weeks	28.14	8.08	1362.85	2.27	<0.001
3 months	22.73	6.31			
6 months	14.57	4.76			
1 year	6.85	3.47			
10 years	1.28	0.54			

[Table/Fig-7]: Analysis of variance (ANOVA) comparing mean DASH scores at different follow-up intervals (6 weeks, 3 months, 6 months, 1 year, and 10 years), demonstrating a statistically significant improvement over time ($p<0.001$).
F-value (1362.85) is much larger than the F critical value (2.277044) and the p-value <0.001

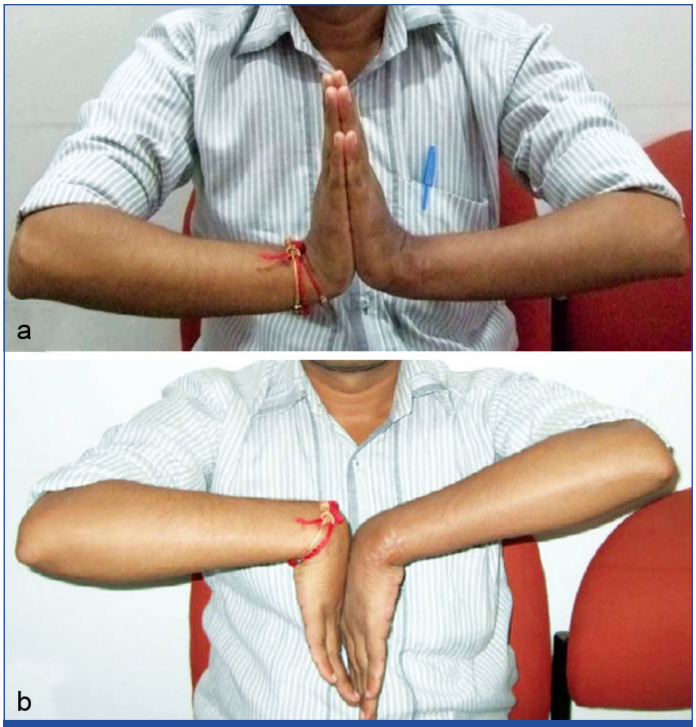
Representative clinical cases illustrating preoperative and postoperative radiographic findings are shown in [Table/Fig-8]. These images demonstrate unstable DRFs preoperatively and stable fixation with volar LCPs postoperatively, confirming adequate fracture reduction and implant positioning.



[Table/Fig-8]: Representative radiographic outcomes following volar Locked Compression Plate (LCP) fixation. Case 1: (a) Preoperative radiograph showing an unstable Distal Radius Fracture (DRF) of the left wrist; (b) Postoperative radiograph showing stable fixation with a volar Locked Compression Plate (LCP) and surgical drain in situ. Case 2: (a) Preoperative radiograph showing an unstable Distal Radius Fracture (DRF); (b) Postoperative radiograph demonstrating stable fracture fixation with a volar Locked Compression Plate (LCP).

Functional wrist movements assessed at three months postoperatively are illustrated in [Table/Fig-9]. Dorsiflexion and palmar flexion of the operated wrist were comparable to the non-operated side, indicating satisfactory early functional recovery.

Paired t-test analysis was performed to compare DASH scores between successive follow-up intervals, as presented in [Table/Fig-10]. All



[Table/Fig-9]: Clinical photographs demonstrating wrist range of motion at three months postoperatively: (a) Dorsiflexion of the operated left wrist comparable to the non-operated side; (b) Palmar flexion of the operated left wrist comparable to the non-operated side.

Duration	Mean Diff	n	t-value	p-value
Pre-op- 6 weeks	71.9	25.0	44.4	<0.001
6 weeks post-op- 3 months	5.4	25.0	11.8	<0.001
3 months - 6 months	8.2	25.0	9.4	<0.001
6 months - 1 year	7.7	25.0	12.1	<0.001
1 year- 10 years	4.1	25.0	9.7	<0.001

[Table/Fig-10]: Paired t-test analysis showing statistically significant differences in mean DASH scores between successive follow-up intervals from preoperative assessment to 10-year follow-up (p<0.001).
Pre-op: Preoperative; Post-op: Postoperative; p-value <0.001

comparisons demonstrated statistically significant improvement, with p-values less than 0.001. These findings confirm consistent and sustained functional recovery following surgical intervention.

Clinically and radiologically, 23 fractures achieved union within three months. Two fractures demonstrated delayed union, requiring up to six months for complete healing; both cases were associated with Fernandez Type V fractures with metaphyseal-diaphyseal comminution. No patient required bone grafting or additional surgical procedures. All surgical wounds healed primarily without infection or wound dehiscence. Two patients experienced transient median nerve symptoms, which resolved with conservative management. No implant-related failures, tendon irritation, nerve injuries, or hardware-related complications were observed during the entire follow-up period.

DISCUSSION

The management of unstable DRFs using open reduction and internal fixation has gained increasing acceptance in recent years, particularly with the evolution of volar LCP technology, as compared to traditional methods such as external fixation and percutaneous pinning [13]. In the present study, 25 patients meeting the inclusion criteria were evaluated to assess the functional and radiological outcomes following fixation with volar LCPs.

The demographic profile of the study population demonstrated that the majority of patients belonged to the economically active age group. The mean age of the patients was 40.9 years, with 64% of cases occurring in individuals aged between 30 and 50 years, followed by 20% in patients older than 50 years and 16% in patients younger than 30 years. Males constituted the predominant group (76%), which is consistent with earlier studies reporting higher incidence of DRFs in males involved in high-energy trauma [14,15]. Road traffic accidents were the most common mode of injury, accounting for 72% of cases, while domestic falls contributed to 28%, a pattern similar to previous observations [16]. Left-sided involvement was more common, observed in 70.83% of cases, which aligns with findings reported in earlier studies [16].

All fractures in the present study were classified according to the Fernandez classification, and surgical intervention was performed using volar LCPs. Primary wound healing was achieved in all cases, with no incidence of wound dehiscence, deep infection, or implant failure. Although hypertrophic scarring was noted in 20% of patients, this did not result in functional limitation. Two patients with Fernandez Type II and Type IV fractures reported mild median nerve symptoms preoperatively, which persisted transiently in the immediate postoperative period without progression. These symptoms resolved with conservative management, and none of the patients required intraoperative carpal tunnel release.

Fracture union was achieved within three months in 92% of cases, while two fractures demonstrated delayed union and required up to six months for complete healing. Both cases were associated with Fernandez Type V fractures characterised by metaphyseal-diaphyseal comminution. None of the patients required bone grafting or secondary surgical procedures, indicating adequate biological and mechanical stability achieved with volar LCP fixation.

Radiological evaluation revealed that anatomical parameters, including radial inclination, radial axial length, and volar tilt, were significantly restored postoperatively and maintained throughout the follow-up period. Even in complex fracture patterns such as Fernandez Type IV and Type V injuries, the fixation method effectively preserved alignment. The preoperative radiological parameters demonstrated considerable variability, whereas postoperative mean values of radial tilt, inclination and radial length were nearer to established normal anatomical ranges. These findings highlight the ability of LCPs to maintain reduction despite early mobilisation.

Functional recovery, assessed by wrist range of motion, showed progressive improvement over time. Dorsiflexion, palmar flexion, ulnar deviation, radial deviation, forearm supination, and pronation improved significantly from the early postoperative period to one year of follow-up, with all improvements being statistically significant (p<0.01). The percentage improvement observed over time further supports the effectiveness of stable fixation in facilitating early rehabilitation and functional recovery.

Functional outcomes assessed using the DASH score demonstrated a consistent and statistically significant reduction across all follow-up intervals. There was a marked improvement within the first six weeks postoperatively, followed by continued improvement at three months, six months, one year, and sustained benefits at the ten-year follow-up. Analysis using ANOVA and paired t-tests confirmed that the reduction in DASH scores at each successive time point was statistically significant (p<0.001). By the end of follow-up, 96% of patients achieved excellent outcomes and 4% achieved good outcomes, indicating minimal residual disability.

The findings of the present study are in agreement with Regar CL et al., who emphasised the importance of open reduction and internal fixation for achieving superior radiological and functional outcomes in unstable DRFs requiring restoration of radiocarpal and radioulnar congruity [17]. Previous studies have also reported favourable outcomes with fragment-specific fixation and volar fixed-angle constructs, citing early functional recovery and stable fracture alignment [18-20]. Reports by Dillingham C et al., demonstrated a similar pattern of progressive improvement in DASH scores following volar plate fixation, which corroborates the findings of the present study [21].

While some studies have suggested that polyaxial plates may reduce hardware-related complications when compared to fixed-angle designs [16-23], the present study observed minimal complications with fixed-angle plates during the follow-up period. The demographic characteristics, union rates, and functional outcomes in the present study were comparable to those reported by Ahmed M et al., [24], Ajith K et al., [23], and other similar investigations [14,15]. However, variations in time to union reported by Orbay JL et al. and Arora R et al., may be attributed to differences in fracture patterns, patient selection, and rehabilitation protocols [19,25].

Overall, the results of this study indicate that volar LCP fixation provides stable anatomical restoration, facilitates early mobilisation, and ensures sustained functional improvement in patients with unstable DRFs.

Limitation(s)

The sample size was relatively small, and the study did not include a comparative group treated with alternative fixation methods such as variable-angle plates, external fixation, or conservative management. Although clinical and radiological follow-up was conducted for one year, long-term outcomes beyond this period were assessed only through annual telephonic feedback up to ten years. Additionally, the study did not evaluate patient-reported outcomes other than the DASH score. Despite these limitations, the findings of the study are consistent with existing literature and provide meaningful insight into the effectiveness of volar LCP fixation for unstable DRFs.

CONCLUSION(S)

The present study concludes that open reduction and internal fixation of unstable DRFs using volar LCPs is a reliable and effective treatment modality. This method provides stable fixation, allows early mobilisation, and results in excellent functional and radiological outcomes with minimal complications across a wide age group. The sustained improvement in functional outcomes observed during long-term follow-up further supports the role of volar LCPs as a preferred treatment option for unstable DRFs. Future studies with larger sample sizes and comparative designs are recommended to further validate these findings and to compare outcomes with other treatment modalities.

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