

Functional Outcomes Following Management of Volar Barton Fractures Fixed with a Variable-Angle Locking Plate: A Prospective Study

Amit Gupta¹, Raj Kumar Bairwa², Ram Khiladi Meena³, Umesh Kumar Meena⁴, Bhavya Raj Singh Yadav⁵

^{1,2,4}Assistant Professor, Department of Orthopaedics, Government Medical College, Kota, Rajasthan, India

³Associate Professor, Department of Orthopaedics, Government Medical College, Kota, Rajasthan, India

⁵Senior Resident, Department of Orthopaedics, Government Medical College, Kota, Rajasthan, India

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Corresponding author: Dr. Raj Kumar Bairwa

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Abstract

Background: Volar Barton fractures are unstable intra-articular fractures of the distal radius associated with volar displacement of the radiocarpal joint. Achieving stable fixation and restoring articular congruity are essential for optimal functional recovery. Variable-angle locking plates allow flexible screw positioning and provide stable fixation of the volar marginal fragment. This study evaluated the functional and radiological outcomes of volar Barton fractures treated with variable-angle locking plate fixation.

Materials and Methods: This prospective, hospital-based interventional study was conducted in the Department of Orthopaedics, Government Medical College, Kota, Rajasthan, India, from June 2024 to May 2025. A total of 46 patients aged 18–60 years with closed, isolated volar Barton fractures underwent open reduction and internal fixation using a variable-angle locking plate through the modified Henry approach. Functional outcomes were assessed at six months using the Disabilities of the Arm, Shoulder and Hand (DASH) score and Gartland and Werley demerit criteria. Radiological outcomes were evaluated using the Sarmiento modification of Lindström criteria. Postoperative complications and the relationship between radiological and functional outcomes were also assessed.

Results: The mean age of the patients was 36.8 ± 10.23 years, and 73.9% were male. Road traffic accidents accounted for 76.1% of injuries. At final follow-up, the mean DASH score was 13.79 ± 5.49 , while the mean Gartland and Werley score was 2.59 ± 2.31 . According to Gartland and Werley criteria, excellent, good, and fair functional outcomes were observed in 67.4%, 28.3%, and 4.3% of patients, respectively, with 95.7% achieving excellent or good outcomes. Radiological outcomes were excellent in 28.3%, good in 54.3%, and fair in 17.4% of patients. Fair radiological outcomes were associated with significantly higher DASH and Gartland and Werley scores compared with good radiological outcomes ($p = 0.001$ for both comparisons). No complications were recorded in 89.1% of patients. Superficial wound infection and hypertrophic scarring occurred in 4.3% each, while complex regional pain syndrome occurred in 2.2%. No non-union, malunion, or implant failure was reported.

Conclusion: Variable-angle locking plate fixation of volar Barton fractures resulted in favourable functional and radiological outcomes at six months, with most patients achieving excellent or good functional recovery. Fair radiological outcomes were associated with significantly poorer functional scores. Variable-angle locking plate fixation appears to be an effective treatment option for these unstable fractures; however, larger comparative studies with longer follow-up are required to validate these findings.

Keywords: Volar Barton Fracture; Distal Radius Fracture; Variable-Angle Locking Plate; Open Reduction And Internal Fixation; DASH Score; Gartland And Werley Score.

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Introduction

Volar Barton fracture is an unstable intra-articular distal radius fracture characterised by a fracture of the volar rim with associated volar subluxation or dislocation of the radiocarpal joint. [1] It is classified as an AO/OTA type B3 injury. Because

of the shearing nature of the injury and tendency for radiocarpal instability, non-operative treatment may result in displacement, malunion, persistent instability, deformity, and post-traumatic arthrosis. [2] Barton's fracture account for 1.2% to 4.2% of

all distal radius fractures. Based on the site and shifting direction of fragments they are classified as dorsal or Volar Barton fracture. [2] The principal objectives of treatment are restoration of articular congruity, maintenance of radial length and palmar tilt, stable fixation, and early wrist mobilisation. [3,4] Volar locking plates provide a buttress effect against volar displacement and permit angularly stable fixation. Variable-angle locking plates offer flexibility in screw trajectory, enabling improved capture of periarticular fragments while potentially avoiding intra-articular screw placement. [5,6]

Although volar plate fixation is widely used for unstable distal radius fractures, studies specifically evaluating functional and radiological outcomes in volar Barton fractures remain limited. The present study assessed functional outcome using DASH and Gartland and Werley scores, radiological outcome using the Sarmiento modification of Lindström criteria, and the relation between radiological and functional outcomes after variable-angle locking plate fixation.

Materials and Methods

Study Design and Setting: This was a prospective, hospital-based interventional study conducted in the Department of Orthopaedics, Government Medical College, Kota, Rajasthan, India, from June 2024 to May 2025. Forty-six consecutive eligible patients were included as per inclusion and exclusion criteria.

Eligibility Criteria

Inclusion Criteria

- Age between 18 and 60 years.
- Closed volar Barton fracture of the distal radius.
- Isolated volar Barton fracture suitable for operative fixation with a variable-angle locking plate.
- Provision of written informed consent.

Exclusion Criteria

- Pathological fracture.
- Presentation more than 4 weeks after injury, classified as delayed presentation.
- Open fracture.
- Associated fractures or major injuries of the same limb.
- Patients not giving consent or unlikely to complete the scheduled postoperative follow-up.

Sample Size: Based on the study on volar Barton fractures fixed with variable locking plates by Karthik & Ethiraj (2022) [7] 65% of patients ($P = 0.65$) achieved excellent functional outcomes based on the Gartland and Werley demerit criteria. Calculating sample size based on $P = 65\%$, a

precision (d) of 15% and dropout rate of around 15%, a sample size of 46 cases is calculated.

Preoperative Assessment: Clinical assessment included documentation of mechanism of injury, swelling, deformity, neurovascular status, and wrist movements. Standard wrist radiographs were obtained. The injured limb was immobilised in a below-elbow slab, elevated, and treated with analgesics and anti-oedema measures. Routine preoperative investigations and anaesthetic assessment were performed. Written informed consent was obtained before surgery.

Surgical Procedure: All fractures were treated by open reduction and internal fixation using a variable-angle locking plate. The modified Henry approach was used. Following exposure of the distal radius, the fracture was reduced using direct manipulation and ligamentotaxis, with provisional Kirschner-wire fixation as required. Plate position and screw length were checked using image intensification. The pronator quadratus was repaired over the plate when feasible. The construct served as a volar buttress to maintain reduction of the volar marginal fragment and distal radial metaphysis.

Postoperative Protocol: Finger mobilisation was initiated immediately after recovery from anaesthesia. Sutures were removed at two weeks, after which wrist rehabilitation comprising active and passive range-of-motion exercises was commenced. Patients were reviewed at 1, 3, and 6 months. At each visit, radiographs were examined for union and implant-related complications, and wrist motion was documented.

Outcome Measures: Functional outcome was assessed at final follow-up using:

- DASH score [8], ranging from 0 (no disability) to 100 (maximum disability).
- Gartland and Werley [9] demerit criteria, categorised as excellent, good, fair, or poor.

Radiological outcome was assessed using the Sarmiento modification of Lindström criteria, incorporating residual deformity, palmar tilt, radial shortening, and radial inclination.

Statistical Analysis: Data were entered into a structured database and analysed using appropriate statistical methods. Continuous variables, including age, wrist range of motion, DASH score, Gartland and Werley demerit score, and radiological parameters, were summarised as mean $\pm$ standard deviation; categorical variables, including sex, mechanism of injury, injured side, functional-outcome category, radiological-outcome category, and complications, were presented as frequencies and percentages. Functional scores were compared across radiological-outcome groups using one-way

analysis of variance or an appropriate non-parametric alternative, depending on the distribution of the data; when pairwise comparisons were performed, the good radiological-outcome group was used as the reference category.

Categorical associations were assessed using the chi-square test or Fisher's exact test when expected cell counts were small. Effect estimates were reported with 95% confidence intervals where applicable. All tests were two-sided, and a p value <0.05 was considered statistically significant. The analysis was performed using SPSS v26.

Ethical Considerations: The ethical clearance was taken from institutional ethical committee. The written informed consent was taken from all study subjects before surgery.

Results

Baseline Characteristics: A total of 46 patients were analysed. Their mean age was 36.8 ± 10.23 years, with an age range of 21–58 years. Males represented 73.9% of the cohort.

Road traffic accidents were the predominant injury mechanism, and the right side was more commonly affected.

Table 1: Baseline characteristics of the study cohort.

Characteristic	Value
Number of patients	46
Age, mean $\pm$ SD (years)	36.8 ± 10.23
Age range (years)	21–58
Male sex	34 (73.9%)
Female sex	12 (26.1%)
Road traffic accident	35 (76.1%)
Fall from height	11 (23.9%)
Right-sided fracture	30 (65.2%)
Left-sided fracture	16 (34.8%)

Range of motion and functional outcome: At final follow-up, wrist flexion and extension were 70.65° and 74.11° , respectively. Forearm rotation was well preserved, with mean supination of 79.78° and pronation of 76.13° . The mean DASH score was 13.79 ± 5.49 , and the mean Gartland and Werley demerit score was 2.59 ± 2.31 .

Table 2: Outcome variable in the present study.

Outcome variable	Mean $\pm$ SD	Range
Wrist flexion	$70.65^\circ \pm 3.45^\circ$	65° – 78°
Wrist extension	$74.11^\circ \pm 3.53^\circ$	68° – 80°
Radial deviation	$10.15^\circ \pm 1.56^\circ$	6° – 12°
Ulnar deviation	$30.70^\circ \pm 3.07^\circ$	25° – 38°
Supination	$79.78^\circ \pm 2.61^\circ$	75° – 85°
Pronation	$76.13^\circ \pm 2.01^\circ$	72° – 80°
DASH score	13.79 ± 5.49	5–30
Gartland and Werley score	2.59 ± 2.31	0–10

According to Gartland and Werley criteria, 31 patients (67.4%) had excellent outcomes, 13 (28.3%) had good outcomes, and 2 (4.3%) had fair outcomes.

Thus, 95.7% of patients achieved an excellent or good functional result.

Radiological Outcome: Thirty-five patients (76.1%) had insignificant residual deformity, while 11 (23.9%) had slight residual deformity. Mean loss of palmar tilt was $4.61^\circ \pm 3.77^\circ$, mean radial shortening was 3.98 ± 1.78 mm, and mean loss of radial inclination was $6.11^\circ \pm 2.77^\circ$. Radiological outcome was excellent in 13 patients (28.3%), good in 25 (54.3%), and fair in 8 (17.4%).

Table 3: Radiological outcomes in the present study.

Radiological measure/outcome	Value
Loss of palmar tilt	$4.61^\circ \pm 3.77^\circ$
Radial shortening	3.98 ± 1.78 mm
Loss of radial inclination	$6.11^\circ \pm 2.77^\circ$
Excellent radiological outcome	13 (28.3%)
Good radiological outcome	25 (54.3%)
Fair radiological outcome	8 (17.4%)

Relation between radiological and functional outcomes: The mean DASH score was similar in the excellent and good radiological-outcome groups. However, fair radiological outcome was associated with a significantly higher DASH score compared with good radiological outcome. Similarly, Gartland and Werley scores were significantly worse in the fair radiological group.

Table 4: Comparison between the radiology outcomes and DASH score and Gartland and Werley score in the present study.

Radiological outcome	DASH score, mean $\pm$ SD	p value vs good	Gartland and Werley score, mean $\pm$ SD	p value vs good
Good	12.9 $\pm$ 5.2	Reference	2.3 $\pm$ 1.6	Reference
Excellent	13.2 $\pm$ 4.9	0.776	1.7 $\pm$ 2.3	0.501
Fair	17.6 $\pm$ 6.4	0.001	4.9 $\pm$ 2.9	0.001

Complications: Forty one patients (89.1%) had no recorded complications. Hypertrophic scar and superficial wound infection occurred in two patients each (4.3%), while one patient (2.2%) developed complex regional pain syndrome. No non-union, malunion, implant failure, or tendon irritation was reported.

Table 5: Post-operative complications in the present study.

Complication	n (%)
None	41 (89.1%)
Hypertrophic scar	2 (4.3%)
Superficial infection	2 (4.3%)
Complex regional pain syndrome	1 (2.2%)

Discussion

This prospective study demonstrated that fixation of closed volar Barton fractures using a variable-angle locking plate resulted in excellent or good functional outcomes, according to the Gartland and Werley scoring system, in 95.7% of patients at six months. The cohort was predominantly young and male, with a mean age of 36.8 years, and road traffic accidents accounted for more than three-quarters of the injuries. These findings suggest that volar Barton fractures in the present population predominantly affected young, active individuals following high-energy trauma.

Similar demographic and injury characteristics were reported by S J and Ethiraj [7] in their prospective study of 40 patients treated with variable locking plates, in which the mean age was 36.43 $\pm$ 10.59 years, 75% of patients were male, and road traffic accidents accounted for 77.5% of injuries. The similarity in patient characteristics strengthens the relevance of their findings for comparison with the present study.

The final range of motion in the present study was satisfactory, with mean flexion, extension, pronation, and supination of 70.65°, 74.11°, 76.13°, and 79.78°, respectively. These values were closely comparable to those reported by S J and Ethiraj [7], who observed mean flexion of 70.63°, extension of 74.3°, pronation of 76.28°, and supination of 79.83° at six months following variable locking plate fixation of volar Barton fractures. The findings were also comparable to those of Khatri et al. [10], who reported mean flexion, extension, pronation, and supination of 71.91°, 76.95°, 77.65°, and 81.86°, respectively, following treatment of

unstable distal radius fractures with variable-angle locking plates. Collectively, these findings support the effectiveness of variable-angle volar plating in facilitating satisfactory wrist mobility following unstable distal radius fractures, including volar Barton injuries.

The mean Disabilities of the Arm, Shoulder and Hand (DASH) score in the present study was 13.79, indicating relatively low residual upper-limb disability at six months. The findings are concordant with those reported by S J and Ethiraj [7] in their study of volar Barton fractures treated with variable locking plates. Jagodzinski et al. [11] also reported a mean DASH score of approximately 2 following variable-angle locking plate fixation for distal radius fractures, although differences in the study population, fracture characteristics, follow-up duration, and rehabilitation protocols may limit direct comparison. In contrast, S J and Ethiraj [7] reported a mean DASH score of 13.98, highlighting that residual disability may persist even after satisfactory surgical fixation of intra-articular fractures. Such differences underline the importance of considering fracture morphology, injury severity, and outcome-assessment timing when interpreting functional scores across studies.

The distribution of functional outcomes in the present study was also consistent with previous literature. In the present series, 67.4% of patients achieved excellent outcomes, 28.3% achieved good outcomes, and 4.3% achieved fair outcomes according to the Gartland and Werley criteria, with no poor outcomes. S J and Ethiraj [7] reported excellent, good, and fair outcomes in 65%, 30%, and 5% of patients, respectively. Similarly, Kolla et al. [12] reported excellent, good, fair, and poor

outcomes in 55%, 35%, 5%, and 5% of patients, respectively, following surgical treatment of volar Barton fractures using an Ellis plate. Kundu et al. [13] reported excellent outcomes in 70% of patients, good outcomes in 16%, and fair outcomes in 14% following volar plating for intra-articular distal radius fractures. Although the overall findings are comparable, variations in fracture complexity, implant design, patient characteristics, rehabilitation protocols, and outcome-assessment criteria may explain differences in the distribution of functional results. The absence of poor outcomes in the present study is encouraging and suggests that stable fixation, appropriate reduction, and postoperative rehabilitation can contribute to favourable short-term functional recovery. Radiological assessment in the present study demonstrated excellent or good outcomes in 82.6% of patients according to the Sarmiento modification of Lindström criteria. The mean residual loss of palmar tilt was 4.61° , while mean radial shortening was 3.98 mm. Despite these residual radiographic deviations, most patients achieved favourable functional outcomes. Similar findings were reported by S J and Ethiraj [7]. Although the distribution of radiological outcomes in the present study differed, the similarity in residual palmar tilt and radial shortening suggests comparable restoration of anatomical parameters following variable locking plate fixation. Nevertheless, the proportion of patients achieving excellent or good radiological outcomes should be interpreted alongside the specific criteria used for classification and the distribution of fracture severity in each cohort.

An important finding of the present study was the association between radiological and functional outcomes. Patients classified as having fair radiological outcomes demonstrated significantly worse DASH and Gartland and Werley scores than those with more favourable radiological results. A similar association was reported by S J and Ethiraj [7], who found that patients with fair radiological outcomes had significantly higher mean DASH scores than those with good radiological outcomes (18.66 ± 6.05 versus 12.94 ± 5.32 ; $p = 0.021$). Their study also demonstrated significantly higher Gartland and Werley demerit scores in the fair radiological outcome group compared with the good outcome group (5.43 ± 2.7 versus 2.32 ± 1.55 ; $p = 0.001$). These findings support the clinical relevance of satisfactory fracture reduction and maintenance of alignment in volar Barton fractures. However, the relationship between radiographic restoration and functional recovery is not necessarily linear, as other factors, including pain, wrist stiffness, soft-tissue injury, and rehabilitation, may influence patient-reported disability and clinical outcomes. Therefore, the objective should be to achieve stable fixation and satisfactory

restoration of joint congruity and alignment while recognising that radiographic perfection alone does not determine functional recovery.

The complication profile in the present study was favourable. Superficial infection occurred in 4.3% of patients and resolved with treatment, while complex regional pain syndrome was reported in 2.2%. No implant failure, non-union, malunion, or extensor tendon complication was recorded. These findings are broadly comparable with those of S J and Ethiraj [7], who reported superficial infection in 5% of patients and complex regional pain syndrome in 2.5%. Kundu et al. [13] also reported superficial wound infections, but no cases of complex regional pain syndrome, non-union, or extensor tendon irritation or rupture. In contrast, Kolla et al. [12] reported wrist arthritis in 15% of patients, malunion in 10%, and extensor pollicis longus tendon irritation in 5%, along with one case of complex regional pain syndrome. Differences in complication rates may reflect variations in fracture severity, surgical technique, implant positioning, screw length, and duration of follow-up. Careful plate placement, intraoperative fluoroscopic assessment of distal screw length, protection of surrounding soft tissues, and timely rehabilitation remain important considerations in minimising complications and promoting recovery.

Consequently, the results should be interpreted as evidence of favourable short-term outcomes rather than definitive proof of superiority. Further studies involving larger patient populations, longer follow-up, and comparative evaluation of different fixation methods are warranted to establish the durability of functional recovery and the long-term risk of post-traumatic arthritis following variable-angle locking plate fixation

Conclusion

Open reduction and internal fixation of closed volar Barton fractures with a variable-angle locking plate through a modified Henry approach provided predominantly excellent-to-good functional outcomes at six months. Most patients achieved good or excellent radiological results, and fair radiological outcome was associated with significantly worse DASH and Gartland and Werley scores. Variable-angle locking plates appear to be an effective fixation option for these unstable intra-articular injuries, although adequately powered comparative studies with longer follow-up are needed.

Strengths and Limitations: The prospective design, use of validated functional scores, serial follow-up, and inclusion of radiological-functional correlation are strengths. Important limitations include the small sample size, single-centre setting, short six-month follow-up, absence of a

comparison group, and lack of serial statistical comparison of functional and radiographic measurements across follow-up intervals. The study included only closed fractures in adults aged 18–60 years, limiting generalisability to open injuries, geriatric fractures, and patients with substantial osteoporotic bone loss.

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