

Study of Precision of Volar Plate Fixation in Distal End Radius Fracture Using Optimal Intraoperative Radiological Evaluation: A Prospective Observational Study

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Abstract

Background: Volar locking plate fixation is the preferred treatment for unstable distal end radius fractures, but inaccurate screw placement, particularly dorsal cortical penetration, can cause extensor tendon irritation or rupture. Standard anteroposterior and lateral fluoroscopic views may fail to detect such penetration. This study evaluated the precision of volar plate fixation using optimal intraoperative radiological evaluation. **Material and Methods:** This prospective observational study was conducted at a tertiary care center and included 80 patients with distal end radius fractures treated with volar locking plate fixation. In addition to standard anteroposterior and lateral views, dorsal tangential (skyline) and tilted views were used routinely to assess screw position and the articular surface. Any screw penetration was corrected by immediate screw exchange. Demographic data, mechanism of injury, AO fracture type, intraoperative findings, postoperative tendon irritation, and radiological parameters (radial height and volar tilt) were recorded. The association between screw penetration and tendon irritation was analyzed using Fisher's exact test. **Results:** The mean age was 54.55 ± 11.15 years (range 36-73), with 40 males and 40 females. Fall on an outstretched hand was the most common mechanism of injury (70%). Intra-articular fractures (AO types B and C) accounted for 80% of cases. Screw penetration was detected intraoperatively in 32 patients (40%), and all underwent screw exchange. Postoperative tendon irritation occurred in 8 patients (10%), all of whom were in the group with screw penetration (8/32, 25%), compared with none of the 48 patients without penetration; this association was statistically significant. The mean postoperative radial height was 8.2 ± 1.4 mm, and the mean volar tilt was $6.1 \pm 1.9^\circ$. **Conclusion:** Routine use of specialized intraoperative views, including the dorsal tangential view, allowed detection and immediate correction of screw penetration in 40% of cases, with acceptable radiological restoration and a low rate of tendon irritation (10%). Screw penetration was associated with tendon irritation, supporting the integration of optimal intraoperative imaging into volar plate fixation. Comparative studies with longer follow-up are needed to confirm whether this approach reduces complications.

Keywords: Distal Radius Fracture, Volar Locking Plate, Intraoperative Fluoroscopy, Dorsal Tangential View, Screw Penetration, Tendon Irritation.

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INTRODUCTION

Distal end radius fractures (DERFs) constitute one of the most frequent fractures seen in orthopedic practice. They comprise about 8-15% of all skeletal fractures, and nearly one-sixth of all fractures reported in emergency departments.^[1,2] They occur in a bimodal pattern. They typically occur after high-energy trauma in younger patients and low-energy falls on an outstretched hand (FOOSH) on osteopenic or osteoporotic bone in the elderly (specifically in post-menopausal women).^[2,3] Their number is rising with the aging of the population and is becoming a public health problem. The distal radius is responsible for transmitting 80% of the axial load across the wrist.^[4] Therefore, restoration of radial height, radial inclination, and volar tilt is crucial, as any remaining malalignment or articular incongruity results in diminished grip strength, limited motion, and post-traumatic osteoarthritis.^[5] Fracture stability guides management. Lafontaine et al. found that factors

predicting instability were dorsal angulation > 20 degrees, dorsal metaphyseal comminution, intra-articular involvement, associated ulnar styloid fracture, and age > 60 years.^[6] If three of these factors occur, the risk of redisplacement following closed reduction is significantly higher.^[6,7] Stable fractures will benefit from cast immobilization; unstable patterns can compromise reduction, malunion, and can lead to joint stiffness.^[7] External fixation is based on ligamentotaxis and is linked to pin-tract

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infection, stiffness, and lack of control of intra-articular fragments.^[8] Percutaneous pinning is a less invasive technique but is not useful for comminuted fractures.

Open reduction and internal fixation (ORIF) with a volar locking plate has emerged as the preferred treatment for unstable distal radius fractures. Its advantages are direct visualization of the fracture, better soft tissue coverage, and fewer extensor tendon complications than dorsal plating.^[9] Fixed-angle locking constructs provide angular stability that is less dependent on bone quality, allowing secure fixation in osteoporotic bone and early mobilization with good functional outcomes.^[10,11] However, accurate screw placement remains a critical challenge. Excessively long screws may penetrate the dorsal cortex or enter the radiocarpal joint, causing extensor tendon irritation or rupture and joint damage.^[12,13] Standard anteroposterior and lateral fluoroscopic views often fail to detect dorsal cortical penetration or subtle intra-articular screw placement.^[13,14] Specialized views, including the dorsal tangential (skyline or dorsal horizon) view and tilted lateral views, improve visualization of the articular surface and screw trajectory and detect screw prominence more reliably.^[14-16] By providing real-time feedback, these views allow immediate correction of errors during surgery. Despite this evidence, their use remains inconsistent in clinical practice, owing to variability in surgeon experience, the absence of standardized protocols, and intraoperative time constraints. There is therefore a need for systematic evaluation of optimal intraoperative radiological guidance in volar plate fixation. The present study aims to evaluate the effectiveness of optimal intraoperative radiological evaluation, incorporating these specialized imaging views, in improving the precision of volar plate fixation in distal end radius fractures, and to assess its impact on screw placement accuracy and complication rates.

MATERIALS AND METHODS

This prospective observational study was conducted in the Department of Orthopedics, MP/029/P/4; School of Medical Sciences, Sri Satya Sai University of Technology and Medical Sciences, Sehore, Madhya Pradesh. Institutional Ethical approval was obtained for the study. Written informed consent was obtained from all the participants of the study after explaining the nature of the study and possible outcomes in vernacular language.

Sample Size: The sample size for the present study was calculated using the standard formula for estimating sample size in prevalence studies: $n = Z^2 \times p \times q/d^2$; Where: n = required sample size; Z = standard normal deviate at desired confidence level; p = estimated prevalence; $q = 1 - p$; d = allowable error. Based on previously published literature, the prevalence of distal radius fractures was estimated to be approximately 8% 67. Using a confidence level of 90% ($Z = 1.64$) and an allowable error of 5%, the calculated sample size was 79.68, which was rounded off to 80 patients.

Inclusion Criteria

1. Distal end radius fracture in patients aged 18 years and above

2. Intra-articular shear fracture.
3. Severe osteoporosis.
4. Metaphyseal communication.
5. Dorsal angulation $>20^\circ$.
6. Radial shortening $>10^\circ$.
7. Ulnar styloid base fracture.

Exclusion Criteria

1. Patients with severe comorbidities.
2. Neurovascular compromise.
3. Compound fractures.
4. Non-united fractures.
5. Polytrauma patients.
6. Patients who are unwilling or unable to provide informed consent.
7. Patients with pathological fractures or fractures resulting from non-traumatic causes.
8. Patients with previous surgical interventions on the affected wrist.

Sampling Technique: A consecutive sampling technique was used for patient recruitment. All patients presenting with distal radius fractures during the study period who met the eligibility criteria and consented to participate were included until the required sample size of eighty patients was achieved.

Preoperative evaluation was done for each case; a detailed history was taken, such as mechanism of trauma, duration of trauma, hand dominance, and/or any other associated injuries. A comprehensive physical examination was conducted, looking at the swelling, deformity, tenderness, and range of motion of the wrist joint. Extensive evaluation and documentation of the neurovascular status of the affected limb were performed.

The standard anteroposterior and lateral radiographs of the wrist joint were taken. The fractures were classified under the frequently used classification systems, and the degree of displacement and articular involvement was observed. As part of the preoperative evaluation, the patient underwent routine laboratory tests, which included a complete blood count, blood sugar, renal function, and coagulation profile.

Study Procedure: After obtaining informed written consent, patients meeting the inclusion criteria were scheduled for surgical fixation using a volar locking plate. All surgeries were performed under regional or general anaesthesia under strict aseptic precautions. The patient was positioned supine with the affected limb placed on a radiolucent hand table to facilitate intraoperative imaging. A standard volar approach to the distal radius was utilized. The fracture fragments were carefully reduced under fluoroscopic guidance, and the reduction was temporarily maintained using Kirschner wires where necessary. The volar locking plate was positioned along the volar surface of the distal radius and secured using locking screws. Intraoperative fluoroscopy was used to assess fracture reduction, plate positioning, and screw length. In addition to conventional anteroposterior and lateral fluoroscopic views, specialized views such as the dorsal tangential view and tilted projections were used to detect possible dorsal cortex screw penetration or intra-articular screw placement. If any screw penetration was detected during intraoperative imaging, the screw was exchanged with an appropriately sized screw to prevent postoperative complications. Postoperative Management: Following surgery,

the operated limb was immobilized using a below-elbow splint for a short duration to allow soft tissue healing. Early finger mobilization was encouraged immediately after surgery. Sutures were removed approximately ten to fourteen days after the procedure. Gradual wrist mobilization exercises were initiated under supervision to restore range of motion and functional strength. Patients were followed up at regular intervals for clinical and radiological assessment.

Outcome Measures: The primary outcome measure in the present study was the precision of screw placement during volar plate fixation, as assessed by intraoperative radiological evaluation. Secondary outcome measures included the incidence of intra-articular screw penetration, dorsal cortical screw prominence, postoperative tendon irritation, and radiological alignment parameters of the distal radius.

Statistical Analysis: All the available data were refined, segregated, and uploaded to an MS Excel spreadsheet and analyzed using SPSS version 26. The continuous variables were represented as mean and standard deviation. Categorical variables were represented as frequencies and percentages. The comparison of two groups was done by Fisher's exact test, and values of $p < 0.05$ were considered significant.

RESULTS

A total of 80 patients with distal end radius fractures who underwent volar plate fixation with optimal intraoperative radiological evaluation were included in the analysis.

Demographics. Patient age ranged from 36 to 73 years, with a mean of 54.55 ± 11.15 years. The largest group was aged

51-60 years ($n = 28, 35\%$), followed by 61-70 years ($n = 20, 25\%$) and 41-50 years ($n = 16, 20\%$). The 30-40 and >70 years groups each comprised 8 patients (10%) [Table 1]. There were 40 males (50%) and 40 females (50%) [Table 1].

Mechanism and side of injury. The most common mechanism of injury was a fall on an outstretched hand (FOOSH) in 56 patients (70%), followed by road traffic accidents in 16 (20%) and sports injuries in 8 (10%). The right side was involved in 48 patients (60%) and the left side in 32 (40%) [Table 2].

Fracture pattern. According to the AO classification, 16 fractures (20%) were Type A (extra-articular), 32 (40%) were Type B (partial articular), and 32 (40%) were Type C (complete articular). Intra-articular involvement was present in 64 patients (80%) and absent in 16 (20%). An associated ulnar styloid fracture was present in 39 patients (48.8%) and absent in 41 (51.2%) [Table 3].

Intraoperative findings. Screw penetration was detected on intraoperative radiological evaluation in 32 patients (40%), and screw exchange was performed in all 32 of these cases. No screw penetration was detected in the remaining 48 patients (60%) [Table 4].

Postoperative outcomes. Postoperative tendon irritation occurred in 8 patients (10%), while 72 patients (90%) had no tendon-related complications. The mean postoperative radial height was 8.2 ± 1.4 mm, and the mean volar tilt was $6.1 \pm 1.9^\circ$ [Table 5].

Association between screw penetration and tendon irritation. All 8 patients with tendon irritation belonged to the group with intraoperative screw penetration (8/32, 25.0%), whereas none of the 48 patients without screw penetration developed tendon irritation. This association was statistically significant (Fisher's exact test, $p = 0.002$) [Table 6].

Table 1: Demographic and Baseline Characteristics of Study Population

Characteristic	Category	Number of Patients (n=80)	Percentage (%)
Age Group (years)	30-40	8	10
	41-50	16	20
	51-60	28	35
	61-70	20	25
	>70	8	10
Age Statistics	Range	36-73 years	
	Mean $\pm$ SD	54.55 ± 11.15	
Gender	Male	40	50
	Female	40	50

Table 2: Mechanism and Side of Injury

Parameter	Category	Number of Patients (n=80)	Percentage (%)
Mechanism of Injury	FOOSH	56	70
	Road Traffic Accident	16	20
	Sports Injury	8	10
Side of Injury	Right	48	60
	Left	32	40

Table 3: Fracture Classification and Associated Injuries

Parameter	Category	Number of Patients (n=80)	Percentage (%)
AO Fracture Type	Type A (Extra-articular)	16	20
	Type B (Partial articular)	32	40
	Type C (Complete articular)	32	40
Intra-Articular Involvement	Present	64	80
	Absent	16	20
Ulnar Styloid Fracture	Present	39	48.8
	Absent	41	51.2

Table 4: Intraoperative Findings and Interventions

Parameter	Category	Number of Patients (n=80)	Percentage (%)
Screw Penetration Detected	Yes	32	40
	No	48	60
Screw Exchange Performed	Yes	32	40
	No	48	60

Table 5: Postoperative Outcomes and Radiological Parameters

Parameter	Category	Value
Postoperative Tendon Irritation	Present	8 (10.0%)
	Absent	72 (90.0%)
Radiological Parameters	Radial Height (mm)	8.2 ± 1.4
	Volar Tilt (°)	6.1 ± 1.9

Table 6: Association Between Intraoperative Screw Penetration and Postoperative Tendon Irritation

Screw Penetration	Tendon Irritation Present	Tendon Irritation Absent	Total
Yes	8	24	32
NO	0	48	48
Total	8	72	80

Fisher's Exact Test p-value: <0.001; statistically significant

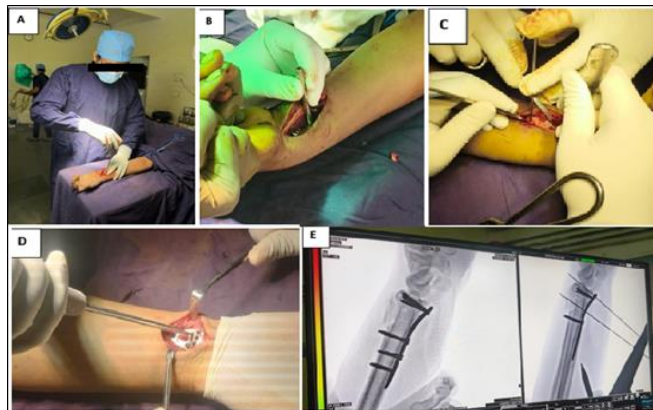


Figure 1: (A&B) Intraoperative technique of volar plate fixation with radiological guidance, volar (Henry) approach; (C) fracture reduction with temporary K-wire fixation; (D) volar locking plate application; (E) AP and lateral fluoroscopic assessment.

DISCUSSION

In this prospective series of 80 patients treated with volar locking plate fixation under optimal intraoperative radiological evaluation, screw penetration was detected in 32 patients (40%) and corrected by screw exchange in every case. Postoperative tendon irritation occurred in 8 patients (10%), all within the group with detected penetration, and radial height and volar tilt were satisfactorily restored. The mean age of 54.55 years, with a peak in the sixth decade, agrees with the bimodal epidemiology of distal radius fractures and the contribution of osteoporosis in older patients.^[1,2,17] Female predominance is usually reported,^[2,17] but our cohort was evenly divided by sex. This probably reflects the inclusion of high-energy injuries (road traffic accidents, 20%; sports injuries, 10%) and the surgical selection of the cohort. Falls on an outstretched hand accounted for 70% of injuries, consistent with earlier reports,^[1,2,18] and the predominance of right-sided fractures (60%) may reflect the tendency to break a fall with the

dominant hand.^[18] Intra-articular fractures (AO types B and C) formed 80% of the series, reflecting the selection of unstable patterns for operative fixation.^[6,19] Residual articular incongruity increases the risk of post-traumatic arthritis,^[5] and volar locking plates allow stable fixation in these fractures,^[10,19] so accurate implant placement is especially important in this group. An associated ulnar styloid fracture was present in 48.8% of patients. Its clinical significance remains debated, and it has not consistently been shown to affect patient-rated outcomes after volar plating.^[20] The 40% rate of screw penetration should be read as a detection rate rather than a complication rate, since every penetrating screw was identified before wound closure. The dorsal cortex of the distal radius has an irregular contour, and standard anteroposterior and lateral views may fail to reveal screw prominence.^[13,14,21] Dorsal tangential (skyline or dorsal horizon) and tilted views improve detection,^[15,16,22,23] which was the rationale for using them routinely here. Reported penetration rates vary with the views used,^[13,14,21,22] and without a control group assessed with conventional views, we cannot state that our detection rate exceeds that of standard fluoroscopy. Tendon irritation is a recognized complication of volar plating, related to dorsal screw prominence and plate position.^[9,12] Its occurrence only in patients with intraoperative penetration supports an association between screw misplacement and tendon-related complications. However, all penetrating screws had been exchanged, yet 8 of these 32 patients (25%) developed irritation. Possible explanations include residual prominence not visible even on tangential views, prominence of the plate itself, or soft-tissue irritation from other causes. Postoperative radial height (8.2 ± 1.4 mm) and volar tilt (6.1 ± 1.9°) were modestly below normal anatomical values, but were comparable with restoration reported after volar locking plate fixation in earlier series.^[10,11] Maintaining volar tilt and joint congruity matters for wrist load transmission and the risk of post-traumatic arthritis (5,24). This study has limitations. It was single-center, of modest size, and had no control group assessed with conventional fluoroscopy. Follow-up was short and did not permit assessment of long-term outcomes such as tendon rupture or arthritis. Functional scores

such as DASH or PRWE were not recorded, and interobserver variability in radiological assessment was not evaluated. Its strengths are the prospective design and the standardized use of specialized views. Finally, routine use of specialized intraoperative views allowed detection and immediate correction of screw penetration in 40% of volar plate fixations, with acceptable radiological restoration and a 10% rate of tendon irritation. Comparative studies with longer follow-up are needed to confirm whether this approach reduces complications.

CONCLUSION

Optimal intraoperative radiological evaluation, including the dorsal tangential and tilted views alongside standard projections, allowed screw penetration to be detected in 40% of volar plate fixations for distal end radius fractures, and every case was corrected during surgery. Postoperative tendon irritation occurred in 10% of patients, all within the group with detected penetration, and radial height and volar tilt were satisfactorily restored. These findings support routine use of specialized intraoperative views to improve the precision of screw placement. Larger comparative studies with longer follow-up and functional outcome measures are needed to confirm whether this approach reduces complications.

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Conflicts of interest

There are no conflicts of interest.

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