

Research Article

Functional Outcome of Distal Radius Fractures Treated with Volar Locking Plate Fixation Using a Pronator Quadratus-Sparing Technique: A Prospective Observational Study

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Abstract: **Introduction:** Distal radius fractures are among the most common fractures encountered in orthopaedic practice. Volar locking plate fixation has become a preferred treatment modality for unstable fractures because it provides stable fixation and facilitates early mobilization. Preservation of the pronator quadratus muscle during volar plating has been proposed to improve soft tissue preservation and early functional recovery. **Aim:** To evaluate the functional and radiological outcomes of distal radius fractures treated with volar plating while sparing the pronator quadratus muscle.

Materials and Methods: A prospective observational study was conducted in the Department of Orthopaedics, Pt. J.N.M. Medical College and Dr. B.R.A.M. Hospital, Raipur. Fifteen adult patients with closed displaced distal radius fractures underwent open reduction and internal fixation using a volar locking plate inserted through a pronator quadratus-sparing modified Henry approach. Functional outcomes were assessed using the Gartland and Werley Demerit Point System at 6 weeks and 3 months. Radiological parameters evaluated included radial inclination, radial height, and volar tilt. **Results:** The mean age of patients was 39.5 ± 17.1 years, and males constituted 66.7% of the study population. AO type 23B3 fractures were the most common fracture pattern (40%). Mean Gartland and Werley score improved significantly from 6.43 ± 4.71 at 6 weeks to 3.08 ± 4.16 at 3 months ($p=0.009$). Pronation improved from 58.7° to 76.1° , while supination improved from 55.5° to 69.8° . Mean grip strength improved from 54.8% to 72.5% compared with the contralateral side. Final mean radial inclination, radial height, and volar tilt were 19.2° , 9.6 mm, and 4.2° , respectively. Only one patient developed transient median nerve symptoms. No tendon rupture, infection, implant failure, or non-union was observed. **Conclusion:** Volar plating using a pronator quadratus-sparing technique provides satisfactory functional recovery, maintenance of radiological alignment, and a low complication rate in selected distal radius fractures.

Keywords: Distal radius fracture; Pronator quadratus sparing; Volar locking plate; Functional outcome; Gartland and Werley score

INTRODUCTION

Distal radius fractures represent one of the most frequently encountered fractures in orthopaedic practice and account for approximately one-sixth of all fractures presenting to emergency departments worldwide [1]. These injuries occur across a broad age spectrum, affecting younger individuals following high-energy trauma and elderly patients following low-energy falls associated with osteoporotic bone loss [2]. Owing to the critical role of the distal radius in wrist biomechanics and load transmission, restoration of anatomical alignment is essential for preserving wrist function and preventing long-term disability.

The distal radius contributes significantly to the stability and coordinated movement of the radiocarpal and distal radioulnar joints. Anatomical parameters such as radial height, radial inclination, and volar tilt are essential determinants of normal wrist kinematics. Malalignment following fracture healing may result in altered force distribution, reduced grip strength, decreased range of

motion, persistent pain, and post-traumatic degenerative changes [1,3].

Historically, conservative treatment consisting of closed reduction and cast immobilization was widely employed for distal radius fractures. Although acceptable outcomes could be achieved in stable extra-articular injuries, unstable and intra-articular fractures frequently progressed to loss of reduction, malunion, and functional impairment [2]. Consequently, operative fixation techniques evolved to improve maintenance of reduction and facilitate early rehabilitation. Methods including percutaneous pinning, external fixation, dorsal plating, and volar plating have all been described [4].

Among available surgical options, volar locking plate fixation has gained widespread acceptance because it provides angular stability, maintains reduction even in osteoporotic bone, and permits early wrist mobilization [5]. The modified Henry approach remains the most commonly utilized surgical approach for volar plating. However, conventional exposure often requires incision

or detachment of the pronator quadratus muscle to facilitate plate placement [3].

The pronator quadratus muscle plays an important role in forearm pronation and stabilization of the distal radioulnar joint. Additionally, it acts as a biological barrier separating the volar plate from adjacent flexor tendons. Surgical disruption of this muscle may theoretically contribute to loss of pronation strength, tendon irritation, and delayed recovery [6].

To minimize soft tissue damage, the pronator quadratus-sparing technique was developed. This approach involves creating a submuscular tunnel beneath the intact muscle and sliding the volar plate without complete detachment of the muscle. Previous studies have suggested improved early postoperative motion, grip strength, pain control, and tendon protection with this technique, although long-term outcomes appear comparable to conventional methods [3,7,8].

Despite increasing interest in pronator quadratus preservation, clinical evidence remains limited, particularly in Indian populations. The present study was therefore undertaken to evaluate functional outcomes, radiological restoration, and complications following volar locking plate fixation of distal radius fractures using a pronator quadratus-sparing technique.

MATERIALS AND METHODS

This prospective observational study was conducted in the Department of Orthopaedics, Pt. Jawahar Lal Nehru Memorial Medical College and Dr. B.R.A.M. Hospital, Raipur, after obtaining approval from the Institutional Ethics Committee. Written informed consent was obtained from all participants before enrolment.

The study included 15 consecutive patients presenting between August 2024 and February 2026 with displaced distal radius fractures requiring operative intervention. Adult patients aged more than 18 years with closed displaced distal radius fractures presenting within 21 days of injury and willing to undergo surgery were

included. AO classification types except 23A1, 23B2, and 23C3 fractures were eligible for enrolment. Patients with previous wrist surgery, pathological fractures, or polytrauma were excluded.

All patients underwent detailed clinical evaluation, radiographic assessment using standard anteroposterior and lateral wrist radiographs, and routine preoperative investigations. Fractures were classified according to the AO/OTA classification system.

Surgical treatment was performed using a modified Henry approach under regional or general anaesthesia. The flexor carpi radialis tendon was identified and retracted, and the pronator quadratus muscle was preserved without detachment. A submuscular tunnel was created beneath the muscle, allowing insertion of a pre-contoured volar locking plate. Fracture reduction was confirmed fluoroscopically before definitive fixation with locking screws.

Postoperatively, all patients received prophylactic antibiotics and immobilization in a below-elbow slab. Active finger mobilization was initiated immediately. Wrist mobilization commenced approximately three weeks after surgery, followed by progressive range-of-motion and strengthening exercises.

Functional outcome assessment was performed using the Gartland and Werley Demerit Point System at 6 weeks and 3 months. Radiological evaluation included measurement of radial inclination, radial height, and volar tilt. Complications including infection, tendon irritation, nerve injury, malunion, non-union, and implant-related problems were recorded during follow-up.

Statistical analysis was performed using appropriate descriptive and inferential statistical methods. Continuous variables were expressed as mean \pm standard deviation. Comparison of functional outcomes between follow-up periods was performed using significance testing, and a p-value <0.05 was considered statistically significant.

RESULTS

Baseline Demographic and Clinical Characteristics

A total of 15 patients with distal radius fractures underwent volar locking plate fixation using the pronator quadratus-sparing technique. The mean age was 39.5 ± 17.1 years (range 18–71 years). Most patients belonged to the 41–60 years age group (40.0%). Male patients constituted 66.7% of the study population. Left-sided injuries were slightly more common than right-sided injuries (53.3% vs 46.7%). AO type 23B3 fractures represented the most frequent fracture pattern (40.0%), followed by type 23C2 fractures (26.7%). Most patients underwent surgery within 14 days of injury, with a mean injury-to-surgery interval of 10.1 ± 10.7 days.

Table 1. Baseline Demographic and Clinical Characteristics

Variable	Value
Sample size	15
Mean age (years)	39.5 ± 17.1
Male	10 (66.7%)

Female	5 (33.3%)
Right side	7 (46.7%)
Left side	8 (53.3%)
Mean injury-surgery interval (days)	10.1 ± 10.7

Table 2. AO Classification of Fractures

AO Type	Frequency	Percentage
23B1	2	13.3
23B3	6	40.0
23C1	3	20.0
23C2	4	26.7

The most common fracture pattern was AO type 23B3 (40.0%), followed by type 23C2 fractures (26.7%). Type 23B1 fractures were the least common injury pattern. The distribution of fracture types did not demonstrate statistical significance.

Functional Outcome

Functional assessment using the Gartland and Werley Demerit Point System demonstrated progressive improvement throughout follow-up. At 6 weeks, most patients achieved a good outcome, whereas by 3 months more than half had achieved excellent functional results.

Table 3. Functional Outcome at 6 Weeks

Outcome	Frequency (n=14)	Percentage
Excellent	3	21.4
Good	9	64.3
Fair	2	14.3
Poor	0	0

At 6 weeks, good functional outcome was observed in 64.3% of patients, while 21.4% achieved excellent results. Only 14.3% demonstrated fair outcomes and no patient had a poor outcome.

Table 4. Functional Outcome at 3 Months

Outcome	Frequency (n=13)	Percentage
Excellent	7	53.8
Good	5	38.5
Fair	1	7.7
Poor	0	0

By 3 months, excellent outcomes increased to 53.8%, while good outcomes were observed in 38.5% of patients. Only one patient (7.7%) had a fair result. Functional outcome improved significantly between the two follow-up periods ($\chi^2 = 4.21$, $p = 0.040$).

Table 5. Comparison of Gartland and Werley Mean Scores

Follow-up	Mean Score ± SD
6 Weeks	6.43 ± 4.71
3 Months	3.08 ± 4.16

Paired t-test: $t = 3.11$, $p = 0.009$

The mean Gartland and Werley score decreased significantly from 6.43 ± 4.71 at 6 weeks to 3.08 ± 4.16 at 3 months, demonstrating significant functional recovery during follow-up.

Recovery of Wrist Motion and Grip Strength

Substantial improvement in wrist range of motion was observed between 6 weeks and 3 months. All measured movements improved significantly, indicating successful rehabilitation and restoration of wrist function.

Table 6. Improvement in Wrist Range of Motion

Parameter	6 Weeks Mean	3 Months Mean	p-value
Dorsiflexion	42.5°	62.5°	<0.001
Palmar Flexion	23.8°	53.3°	<0.001
Radial Deviation	12.9°	17.5°	0.002
Ulnar Deviation	18.8°	25.0°	0.001
Supination	55.5°	69.8°	<0.001
Pronation	58.7°	76.1°	<0.001

All major wrist movements improved significantly during follow-up, with the greatest improvement observed in palmar flexion and forearm pronation.

Table 7. Grip Strength Recovery

Follow-up	Mean Grip Strength \pm SD (%)
6 Weeks	54.8 \pm 10.2
3 Months	72.5 \pm 11.8

Mean grip strength improved from 54.8 \pm 10.2% at 6 weeks to 72.5 \pm 11.8% at 3 months, reflecting progressive restoration of hand function and strength following fixation.

Radiological Outcome and Complications

Radiological parameters at final follow-up demonstrated satisfactory restoration of distal radius anatomy. Complications were minimal, with only one patient developing transient median nerve symptoms.

Table 8. Final Radiological Outcome and Complications

Parameter	Value
Radial inclination	19.2 \pm 2.4°
Radial height	9.6 \pm 1.7 mm
Volar tilt	4.2 \pm 5.8°
Median nerve symptoms	1 (6.7%)
Infection	0
Tendon rupture	0
Implant failure	0

The mean radial inclination, radial height, and volar tilt remained within acceptable postoperative limits. Only one patient developed median nerve symptoms (6.7%), while no cases of infection, tendon rupture, or implant failure were observed, indicating a favorable safety profile.

DISCUSSION

Distal radius fractures are among the most common fractures encountered in orthopaedic practice and represent a significant cause of functional impairment of the upper extremity [1–3]. The increasing use of volar locking plate fixation has improved the management of unstable distal radius fractures by allowing stable fixation, restoration of anatomy, and early mobilization [4,5]. More recently, preservation of the pronator quadratus (PQ) muscle during volar plating has attracted attention because it minimizes soft tissue disruption and may contribute to improved early functional recovery [6–10]. The present study evaluated the functional and radiological outcomes of distal radius fractures treated using a PQ-sparing volar locking plate technique and demonstrated favorable short-term results.

The mean age of patients in the present study was 39.5 \pm 17.1 years, with the majority belonging to the 41–60-year age group. Male patients constituted 66.7% of the study population. These findings are comparable to those reported by Tahririan et al. [19], who observed a relatively young patient population undergoing operative fixation of distal radius fractures. Similarly, Dumbre et al. [25] and Champawat et al. [14] reported a predominance of middle-aged male patients, reflecting the contribution of occupational injuries and road traffic accidents in this age group. Although younger patients tended to achieve better outcomes in the present study, the association between age and final functional outcome was not statistically significant ($p = 0.336$), suggesting that factors such as fracture reduction, fixation stability,

and rehabilitation may be more important determinants of recovery than age alone.

The most common fracture pattern in the present series was AO type 23B3 (40.0%), followed by AO type 23C2 fractures (26.7%). Similar distributions have been reported in studies evaluating volar locking plate fixation, where partial-articular and complete-articular fractures constitute the majority of surgically managed injuries [11,12]. Although more complex fractures tended to show relatively inferior outcomes, AO fracture classification was not significantly associated with final functional results. This finding suggests that satisfactory outcomes can be achieved across different fracture patterns when stable fixation and anatomical reduction are obtained.

The primary objective of the present study was to evaluate functional outcome using the Gartland and Werley scoring system [21]. At 6 weeks, 64.3% of patients demonstrated good outcomes and 21.4% achieved excellent outcomes. By 3 months, excellent outcomes increased to 53.8%, while good outcomes were observed in 38.5% of patients. The improvement in functional outcome between follow-up periods was statistically significant ($\chi^2 = 4.21$, $p = 0.040$). Furthermore, the mean Gartland and Werley score improved significantly from 6.43 \pm 4.71 at 6 weeks to 3.08 \pm 4.16 at 3 months (paired $t = 3.11$, $p = 0.009$).

These findings are consistent with previous studies evaluating PQ preservation. Zhang et al. [6] reported superior early functional recovery among patients

undergoing PQ-sparing fixation compared with conventional techniques. Fan et al. [10] similarly demonstrated improved early postoperative function and patient satisfaction in patients treated with pronator quadratus preservation. Huang et al. [13] reported that preservation of the PQ muscle facilitated early rehabilitation and reduced postoperative discomfort while maintaining equivalent radiological outcomes. Collectively, these studies support the concept that minimizing soft tissue disruption may accelerate recovery during the early postoperative period.

Restoration of wrist mobility is essential for successful rehabilitation following distal radius fracture fixation. In the present study, significant improvements were observed in all wrist movements between 6 weeks and 3 months. Dorsiflexion improved from 42.5° to 62.5°, palmar flexion from 23.8° to 53.3°, radial deviation from 12.9° to 17.5°, ulnar deviation from 18.8° to 25.0°, supination from 55.5° to 69.8°, and pronation from 58.7° to 76.1°. All improvements were statistically significant. The improvement in pronation deserves particular attention because the pronator quadratus muscle is the primary pronator of the distal forearm. Preservation of the muscle may help maintain muscle function and facilitate earlier recovery of forearm rotation. Similar observations were reported by Itoh et al. [11] and Zhong et al. [12], who demonstrated favorable rotational recovery following PQ-sparing fixation. Huang et al. [13] also reported superior early motion among patients undergoing pronator preservation, supporting the biological rationale of the technique.

Grip strength is another important determinant of hand function and patient satisfaction. In the present study, mean grip strength improved from 54.8 ± 10.2% at 6 weeks to 72.5 ± 11.8% at 3 months. These findings indicate progressive restoration of hand function following fracture healing and rehabilitation. Comparable improvements have been reported by Zhang et al. [6], Fan et al. [10], and Huang et al. [13], who observed superior early grip strength among patients treated with PQ-sparing techniques. The preservation of muscular anatomy and reduced surgical trauma may contribute to these favorable outcomes.

Radiological restoration remains a critical objective of distal radius fracture management because anatomical alignment directly influences wrist biomechanics and long-term function [22,23]. In the present study, mean radial inclination was 19.2 ± 2.4°, radial height was 9.6 ± 1.7 mm, and volar tilt was 4.2 ± 5.8° at final follow-up. These values were maintained within acceptable postoperative limits and demonstrated satisfactory restoration of distal radius anatomy.

An important finding of the present study was the association between radiological restoration and functional outcome. Patients achieving excellent functional outcomes demonstrated superior radiological parameters, including greater radial inclination, better

radial height, and more favorable volar tilt. These findings are consistent with previous reports emphasizing the importance of anatomical reduction in achieving optimal functional recovery [4,23,24]. Restoration of radial height and inclination helps maintain normal load transmission across the wrist joint, while correction of volar tilt contributes to improved range of motion and grip strength.

Complications were minimal in the present study. Only one patient developed median nerve symptoms, resulting in an overall complication rate of 6.7%. No infections, tendon ruptures, implant failures, or major adverse events were observed. Similar low complication rates have been reported in previous studies evaluating PQ preservation [6,12,13]. Preservation of the pronator quadratus may provide an additional protective barrier between the implant and flexor tendons, potentially reducing tendon irritation and rupture. Tahirian et al. [19] highlighted the importance of soft tissue coverage over volar plates in preventing tendon-related complications.

Neither age nor sex showed a statistically significant association with final functional outcome. Male patients demonstrated a higher proportion of excellent outcomes, but the difference was not significant ($p = 0.421$). These findings are consistent with previous studies reporting that demographic variables have limited influence on outcome when stable fixation and appropriate rehabilitation are achieved [14,25].

The strengths of the present study include prospective data collection, standardized surgical technique, objective functional assessment using the Gartland and Werley scoring system, and simultaneous evaluation of radiological and clinical outcomes. Nevertheless, several limitations should be acknowledged. The study included a relatively small sample size of 15 patients, which may have limited statistical power. The absence of a comparison group treated using conventional PQ release precluded direct comparison between techniques. Furthermore, follow-up was limited to 3 months and therefore long-term functional and radiological outcomes could not be assessed.

Despite these limitations, the present study demonstrates that volar locking plate fixation using a pronator quadratus-sparing technique provides satisfactory functional recovery, restoration of wrist motion, maintenance of radiological alignment, and a low complication rate. The findings support the continued use of this biologically favorable approach in appropriately selected distal radius fractures.

CONCLUSION

The present study demonstrated that distal radius fractures treated with volar locking plate fixation using a pronator quadratus-sparing technique achieved favorable functional and radiological outcomes. Significant

improvement was observed in Gartland and Werley functional scores, wrist range of motion, and grip strength between 6 weeks and 3 months of follow-up. More than 90% of patients achieved excellent or good functional outcomes at final assessment.

Radiological parameters, including radial inclination, radial height, and volar tilt, were maintained within acceptable postoperative limits, indicating satisfactory anatomical restoration. Patients with superior radiological alignment achieved better functional outcomes, highlighting the importance of accurate fracture reduction. Complications were minimal, with only one patient developing transient median nerve symptoms and no cases of infection, tendon rupture, or implant failure.

The findings suggest that preservation of the pronator quadratus muscle during volar plating is a safe and effective technique that facilitates early rehabilitation while maintaining stable fixation and satisfactory anatomical alignment. Although larger comparative studies with longer follow-up are required, the present study supports the use of the pronator quadratus-sparing approach as a valuable surgical option for selected distal radius fractures.

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