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Functional outcome and complications following open reduction and internal fixation of distal radius fractures using volar locking plates: A clinical and radiological assessment

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Abstract

Background: Distal radius fractures are common orthopaedic injuries that may result in pain, restricted wrist mobility, and functional disability. Open reduction and internal fixation (ORIF) using volar locking plates provides stable fixation and facilitates anatomical reduction and early rehabilitation.

Aim: To evaluate the functional outcomes, radiological results, fracture union, and postoperative complications following volar locking plate fixation of distal radius fractures.

Materials and Methods: This hospital-based prospective observational study was planned in the Department of Orthopaedics, Government Medical College, Solapur, Maharashtra, India, over six months. A total of 50 patients aged 18 years or older with distal radius fractures requiring operative management were included. All patients underwent ORIF using volar locking plates. Clinical assessment included pain, wrist range of motion, grip strength, and functional recovery. Radiological evaluation included radial height, radial inclination, volar tilt, maintenance of reduction, and fracture union. Postoperative complications were documented during follow-up.

Results: The study was designed to assess functional recovery, radiological restoration, and complications following volar locking plate fixation. Verified patient-level results and statistical analyses were not available for reporting; therefore, definitive outcome estimates cannot be presented.

Conclusion: Volar locking plate fixation is an established surgical option for appropriately selected distal radius fractures. Systematic clinical and radiological follow-up is essential to evaluate functional recovery, fracture healing, and complications.

Keywords: Distal Radius Fracture, Volar Locking Plate, Open Reduction and Internal Fixation, Functional Outcome, Radiological Assessment, Postoperative Complications.

Introduction

Distal radius fractures are among the most common fractures encountered in orthopaedic practice and account for a substantial proportion of injuries involving the upper extremity. These fractures occur across a wide age range and are commonly associated with falls on an outstretched hand, road traffic accidents, sports-related trauma, and falls from height. In younger individuals, high-energy trauma is an important mechanism, whereas in older adults, low-energy falls associated with reduced bone strength frequently contribute to fracture occurrence. The clinical presentation ranges from simple extra-articular fractures to complex intra-articular injuries involving displacement, comminution, and disruption of the radiocarpal joint surface. The treatment of these fractures aims to restore anatomical alignment, achieve stable fixation, facilitate early mobilisation, and minimise long-term functional disability.[1,2]

The management of distal radius fractures depends on several factors, including patient age, activity level, fracture configuration, articular involvement, displacement, bone quality, associated injuries, and functional requirements. Although conservative treatment with closed reduction and cast immobilisation remains appropriate for selected fractures, operative intervention is often considered for displaced or unstable fractures in which acceptable alignment cannot be achieved or maintained. Intra-articular incongruity, loss of radial height, abnormal radial inclination, and altered volar tilt may adversely affect wrist mechanics and contribute to persistent pain, restricted movement, reduced grip strength, and post-traumatic degenerative changes.[2,3]

Open reduction and internal fixation (ORIF) using volar locking plates has become an established surgical technique for managing unstable and displaced distal radius fractures. The volar approach provides direct access to the fracture site and facilitates anatomical reduction under fluoroscopic guidance. Locking screws engage with the plate to create a fixed-angle construct, offering stability in metaphyseal bone and allowing secure fixation of multiple fracture fragments. These characteristics are particularly useful in osteoporotic bone and in selected complex fracture patterns. Stable fixation may also permit earlier wrist mobilisation and rehabilitation, potentially improving functional recovery.[4,5]

Despite these advantages, volar locking plate fixation is not free from complications. Reported problems include wound infection, postoperative stiffness, median nerve symptoms, flexor or extensor tendon irritation or rupture, complex regional pain syndrome, hardware prominence, intra-articular screw penetration, loss of reduction, and malunion. The occurrence of these complications may depend on fracture severity, surgical technique, plate positioning, screw length, rehabilitation, and patient-related factors. Careful preoperative planning, appropriate implant placement, intraoperative fluoroscopic assessment, and regular postoperative follow-up are therefore important components of treatment.[5,6]

Assessment of treatment success requires both clinical and radiological evaluation. Clinical assessment includes pain, wrist and forearm range of motion, grip strength, ability to perform daily activities, and patient-reported disability. Validated outcome instruments, such as the

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Disabilities of the Arm, Shoulder and Hand (DASH) questionnaire and the Patient-Rated Wrist Evaluation (PRWE), provide standardised measures of upper-limb disability and wrist-specific symptoms[7,8]. Radiological assessment evaluates restoration and maintenance of radial height, radial inclination, volar tilt, articular congruity, and fracture union. These parameters help determine whether anatomical reduction has been achieved and maintained during healing.

The AO/OTA classification provides a systematic method of categorising distal radius fractures according to their anatomical and articular involvement. Type A fractures are extra-articular, Type B fractures are partial-articular, and Type C fractures are complete-articular. This classification is useful for documenting fracture morphology and examining whether increasing fracture complexity is associated with differences in functional recovery or complications.[9]

Although volar locking plates provide stable fixation in many unstable distal radius fractures, functional recovery is influenced by multiple factors, and satisfactory radiological alignment does not necessarily guarantee an equivalent functional result. Comparative studies have demonstrated the importance of evaluating patient-reported outcomes alongside anatomical restoration and procedure-related complications[4,10]. Consequently, systematic clinical and radiological assessment is essential to understand the benefits and limitations of this surgical technique in routine orthopaedic practice.

The present study, entitled "Functional Outcome and Complications Following Open Reduction and Internal Fixation of Distal Radius Fractures Using Volar Locking Plates: A Clinical and Radiological Assessment," was undertaken at the Department of Orthopaedics, Government Medical College, Solapur, Maharashtra, India, over a period of six months in 50 patients. The study aimed to evaluate functional outcomes following volar locking plate fixation, assess radiological restoration and fracture union, document postoperative complications, and examine the relationship between fracture classification and functional recovery.

Materials And Methods

Study Design and Setting

The present study, entitled "Functional Outcome and Complications Following Open Reduction and Internal Fixation of Distal Radius Fractures Using Volar Locking Plates: A Clinical and Radiological Assessment," was conducted as a hospital-based prospective observational study at the Department of Orthopaedics, Government Medical College (GMC), Solapur, Maharashtra, India. The study was undertaken over a period of six months to evaluate functional recovery, radiological outcomes, and postoperative complications following open reduction and internal fixation (ORIF) of distal radius fractures using volar locking plates.

Study Population

A total of 50 patients with distal radius fractures who fulfilled the eligibility criteria and underwent surgical fixation using a volar locking plate were included in the study. Patients were assessed clinically and radiologically during the postoperative follow-up period to evaluate fracture healing, restoration of anatomical alignment, wrist function, and procedure-related complications.

Inclusion Criteria

1. Patients aged 18 years or older with distal radius fractures requiring operative management.

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2. Patients with displaced, unstable, or intra-articular distal radius fractures considered suitable for volar locking plate fixation.
3. Patients undergoing primary ORIF using a volar locking plate.
4. Patients willing to participate in the study and provide informed consent.
5. Patients available for the planned clinical and radiological follow-up.

Exclusion Criteria

1. Open fractures with severe soft-tissue injury that precluded the planned fixation technique.
2. Pathological fractures of the distal radius.
3. Previous fracture, deformity, or surgery involving the affected wrist that could interfere with functional assessment.
4. Associated major neurovascular injuries affecting the operated limb.
5. Patients with incomplete follow-up or insufficient clinical and radiological records for outcome assessment.

Preoperative Assessment

All eligible patients underwent a detailed clinical evaluation, including history of injury, mechanism of trauma, affected side, hand dominance, associated injuries, and relevant medical history. The wrist was examined for swelling, deformity, tenderness, skin condition, and range of motion where feasible. Distal neurovascular status was documented, including median nerve function and digital circulation.

Standard anteroposterior and lateral radiographs of the affected wrist were obtained to assess fracture configuration, displacement, articular involvement, radial height, radial inclination, and volar or dorsal tilt. Fractures were classified using an established classification system, such as the AO/OTA classification, wherever applicable. Routine preoperative investigations and anaesthetic evaluation were completed according to institutional protocols.

Surgical Procedure

All patients underwent ORIF of the distal radius using a volar locking plate under appropriate anaesthesia. The procedure was performed using a standard volar approach, commonly the modified Henry approach, according to the fracture configuration and surgeon preference.

After exposure of the fracture site, reduction was achieved under direct vision and fluoroscopic guidance. Temporary fixation was performed when required, followed by application of an appropriately sized volar locking plate. Locking screws were inserted to obtain stable fixation while avoiding intra-articular screw penetration. Intraoperative fluoroscopy was used to confirm fracture reduction, restoration of alignment, plate position, and screw length.

The wound was closed in layers, and a sterile dressing was applied. Postoperative immobilisation, when required, was provided according to fracture stability and the treating surgeon's protocol.

Postoperative Management and Rehabilitation

Postoperative management included analgesia, wound care, monitoring of distal neurovascular status, and assessment for early complications. Finger mobilisation was encouraged immediately when clinically appropriate. Wrist mobilisation and physiotherapy were initiated according to fixation stability, soft-tissue condition, and the treating surgeon's advice.

Patients were counselled regarding rehabilitation, home exercises, and the importance of follow-up. Progressive wrist and forearm mobilisation was encouraged as

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tolerated, with strengthening exercises introduced after adequate clinical and radiological evidence of fracture healing.

Clinical and Functional Assessment

Functional outcomes were assessed using the Gartland and Werley demerit-point system. The total score was used to classify outcomes as excellent (0–2 points), good (3–8 points), fair (9–20 points), or poor (more than 20 points). Clinical assessment also included wrist flexion and extension, forearm pronation and supination, grip strength, pain, and functional use of the affected hand.

Radiological Assessment

Standard anteroposterior and lateral wrist radiographs were evaluated postoperatively and during follow-up. Radiological parameters included radial height, radial inclination, volar tilt, articular congruity, maintenance of fracture reduction, and evidence of fracture union.

Fracture union was assessed using clinical findings and serial radiographs. Delayed union, loss of reduction, malunion, hardware loosening, screw penetration, and other radiological abnormalities were documented whenever present.

Assessment of Complications

Postoperative complications were recorded throughout the study period. These included wound infection, tendon irritation or rupture, median nerve symptoms, complex regional pain syndrome, hardware-related complications, stiffness, delayed union, malunion, and loss of reduction. Complications were classified according to their clinical significance and the treatment required.

Follow-up Schedule

Patients were evaluated postoperatively and at scheduled follow-up visits, according to institutional practice. A typical assessment schedule included the immediate postoperative period and follow-up at approximately 2 weeks, 6 weeks, 3 months, and 6 months where feasible. The final follow-up point was determined by the actual study protocol and enrolment dates.

Statistical Analysis

Data were to be entered into Microsoft Excel and analysed using SPSS software. Categorical variables, including fracture type, affected side, and complications, were expressed as frequencies and percentages. Continuous variables, including age, range of motion, grip strength, and functional scores, were summarised using means and standard deviations or medians and interquartile ranges, depending on the distribution of data.

Preoperative and postoperative measurements were to be compared using the paired Student's t-test for normally distributed continuous data or the Wilcoxon signed-rank test for non-normally distributed data. Associations between categorical variables were to be evaluated using the chi-square test or Fisher's exact test, as appropriate. A p-value of less than 0.05 was considered statistically significant.

Results and Observations

The study was designed to evaluate the functional outcome, radiological restoration, fracture union, and complications following ORIF of distal radius fractures using volar locking plates in 50 patients treated at GMC Solapur over six months.

Table 1: Age-wise Distribution of Study Participants (n = 50)

Age group (years)	Number of patients	Percentage (%)
18–30	8	16.0
31–40	10	20.0
41–50	12	24.0

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51–60	11	22.0
61–70	6	12.0
Above 70	3	6.0
Total	50	100.0

Observation: The illustrative distribution shows that the largest proportion of patients belonged to the 41–50-year age group (24%), followed by the 51–60-year age group (22%).

Table 2: Gender Distribution of Patients

Gender	Number of patients	Percentage (%)
Male	29	58.0
Female	21	42.0
Total	50	100.0

Observation: In this illustrative dataset, males constituted 58% of the study population and females constituted 42%.

Table 3: Mode of Injury

Mode of injury	Number of patients	Percentage (%)
Fall on an outstretched hand / fall from standing height	27	54.0
Road traffic accident	17	34.0
Fall from height	4	8.0
Sports-related injury	2	4.0
Total	50	100.0

Observation: A fall on an outstretched hand or from standing height was the most frequent mechanism in the illustrative dataset, accounting for 54% of cases, followed by road traffic accidents (34%).

Table 4: Distribution According to Fracture Classification

AO/OTA fracture type	Number of patients	Percentage (%)
Type A — Extra-articular	18	36.0
Type B — Partial articular	10	20.0
Type C — Complete articular	22	44.0
Total	50	100.0

Observation: Complete articular fractures (Type C) accounted for the largest proportion of cases in the illustrative distribution (44%). Extra-articular fractures accounted for 36%, while partial articular fractures represented 20%.

Table 5: Distribution According to the Side of Injury

Side involved	Number of patients	Percentage (%)
Right wrist	28	56.0
Left wrist	22	44.0
Total	50	100.0

Observation: The right wrist was involved in 56% of the illustrative cases, while the left wrist was involved in 44%.

Table 6: Clinical and Functional Outcome at Final Follow-up

Functional outcome	Number of patients	Percentage (%)
Excellent	20	40.0
Good	21	42.0
Fair	7	14.0
Poor	2	4.0
Total	50	100.0

Observation: In the illustrative dataset, excellent or good functional outcomes were observed in 41 of 50 patients (82%). Seven patients (14%) had fair outcomes, while two patients (4%) had poor outcomes.

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Table 7: Range of Motion Before Surgery and at Final Follow-up

Movement	Preoperative mean (°)	Final follow-up mean (°)
Wrist flexion	20	55
Wrist extension	15	58
Forearm pronation	55	78
Forearm supination	45	75

Table 8: Radiological Parameters Before and After Fixation

Radiological parameter	Preoperative mean	Postoperative mean
Radial height (mm)	5.5	11.0
Radial inclination (°)	13	22
Volar tilt (°)	−12	8

Observation: The illustrative values demonstrate restoration of radial height, radial inclination, and volar tilt following plate fixation.

Table 9: Time to Fracture Union

Time to union	Number of patients	Percentage (%)
6–8 weeks	16	32.0
9–12 weeks	29	58.0
More than 12 weeks	5	10.0
Total	50	100.0

Observation: In this illustrative distribution, 90% of patients achieved fracture union within 12 weeks, while 10% required more than 12 weeks. Delayed union should be defined prospectively and confirmed using the study's clinical and radiological criteria.

Table 10: Postoperative Complications

Complication	Number of patients	Percentage (%)
Wrist stiffness	5	10.0
Median nerve symptoms	3	6.0
Tendon irritation	2	4.0
Superficial wound infection	2	4.0
Complex regional pain syndrome	1	2.0
Loss of reduction/malunion	1	2.0
No recorded complication	36	72.0

Table 11: Association Between AO/OTA Fracture Classification and Functional Outcome at Final Follow-up (n = 50)

Fracture type	Excellent	Good	Fair	Poor	Total
Type A — Extra-articular	9	7	2	0	18
Type B — Partial articular	4	5	1	0	10
Type C — Complete articular	7	9	4	2	22
Total	20	21	7	2	50

Discussion

Distal radius fractures represent a common orthopaedic injury that may result in persistent pain, restricted wrist mobility, reduced grip strength, and functional disability if satisfactory reduction and rehabilitation are not achieved. The present study was designed to assess

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functional outcomes, radiological restoration, fracture union, and postoperative complications following ORIF using volar locking plates in 50 patients over six months at GMC Solapur. The discussion below relates the study objectives and illustrative findings to previously published literature. Because the numerical results provided earlier are examples rather than verified patient observations, the comparisons should be revised after the actual data have been analysed.

Age and Gender Distribution

The illustrative age distribution showed that the largest proportion of patients belonged to the 41–50-year age group, followed by those aged 51–60 years. Distal radius fractures occur in both younger individuals following high-energy trauma and older individuals following low-energy falls, particularly in the presence of reduced bone strength. The age profile of a hospital-based study depends on referral patterns, injury mechanisms, treatment selection, and the population served by the institution. Therefore, age distribution should be interpreted in relation to the local study population rather than considered a universal pattern.

The illustrative dataset also showed a higher proportion of male patients than female patients. Such a distribution may reflect differences in occupational exposure, road traffic injuries, physical activity, and the age composition of the study population. However, gender predominance varies between settings and should not be generalised without supporting epidemiological evidence.

Mechanism of Injury

Falls on an outstretched hand or falls from standing height constituted the largest category in the illustrative results, followed by road traffic accidents. The mechanism of injury is clinically relevant because it may influence fracture displacement, comminution, articular involvement, and associated soft-tissue damage. High-energy injuries can produce complex fracture patterns, whereas low-energy injuries in older adults may be associated with osteoporotic bone and metaphyseal comminution.

Understanding the mechanism of injury helps guide preoperative assessment and surgical planning. Nevertheless, the relationship between injury mechanism and functional recovery must be established using the actual study data, including fracture classification and relevant patient characteristics.

Fracture Classification and Surgical Management

The illustrative fracture distribution included extra-articular (Type A), partial-articular (Type B), and complete-articular (Type C) fractures according to the AO/OTA classification. Complete-articular fractures represented the largest group in the example dataset. These fractures generally present greater challenges in restoring articular congruity because the joint surface is separated from the radial shaft, often with multiple fragments or metaphyseal comminution. The AO/OTA classification provides a standardised framework for documenting fracture morphology and communicating the severity of the injury.[1]

Volar locking plate fixation allows direct reduction of the fracture and stable fixation of the distal fragments. The fixed-angle design may be particularly useful when the distal fragments are small or bone quality is compromised. Orbay and Fernandez described the role of volar fixation in managing unstable distal radius fractures, emphasising the importance of an appropriate surgical approach and stable internal fixation.[2]

However, the complexity of a fracture alone does not determine the final functional outcome. Reduction

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quality, soft-tissue injury, associated carpal injuries, rehabilitation, patient compliance, and pre-existing functional limitations may also influence recovery. Consequently, fracture classification should be considered alongside clinical and radiological outcome measures.

Functional Outcome Following Volar Locking Plate Fixation

In the illustrative results, 41 of 50 patients (82%) achieved excellent or good functional outcomes, while the remaining patients had fair or poor outcomes. If confirmed in the actual study, such a distribution would suggest favourable functional recovery in most patients. However, a definitive conclusion requires confirmation of the scoring instrument used, its scoring criteria, and the final follow-up findings.

Functional assessment is an essential component of distal radius fracture management because satisfactory radiographic alignment does not always translate into equivalent patient-reported recovery. The DASH questionnaire measures disability and symptoms affecting the upper extremity, whereas the PRWE specifically evaluates wrist pain and disability[3,4]. Consistent use of a validated instrument improves comparability between patients and studies.

Evidence from systematic reviews indicates that volar locking plate fixation can provide earlier functional recovery and improved radiographic alignment in selected patients. However, the magnitude of benefit depends on the comparator treatment, patient age, fracture characteristics, and follow-up duration. A systematic review by Oldrini and colleagues found that early clinical advantages were not consistently maintained at longer follow-up across all outcomes[5]. Similarly, comparative evidence has shown that better radiographic results do not necessarily produce clinically important differences in patient-reported outcomes at 12 months[6].

Thus, functional outcome should be interpreted using both objective clinical findings and validated patient-reported measures rather than relying exclusively on the overall excellent or good categories.

Improvement in Wrist and Forearm Range of Motion

The illustrative results demonstrated improvement in wrist flexion, extension, pronation, and supination between the preoperative assessment and final follow-up. Restoration of wrist and forearm movement is an important treatment objective because restriction can interfere with personal care, lifting, writing, and other routine activities.

Stable internal fixation may facilitate earlier mobilisation when the fracture and soft tissues permit. Nevertheless, postoperative stiffness may occur because of swelling, pain, immobilisation, capsular restriction, tendon adhesions, or inadequate rehabilitation. The extent of functional improvement depends on the severity of the initial injury and the timing and consistency of postoperative physiotherapy.

A systematic review and meta-analysis by Wang and colleagues comparing volar locking plates with external fixation reported differences in some functional measures during follow-up, although the findings varied according to the outcome measure and assessment time[7]. These findings support the importance of evaluating range of motion at standardised intervals rather than assuming that anatomical fixation alone ensures complete functional recovery.

For the present study, preoperative and final follow-up measurements should be reported as mean values with

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standard deviations, alongside the statistical significance of within-patient changes. If available, grip strength and a validated functional score would provide additional information about recovery.

Radiological Restoration and Fracture Union

Restoration of radial height, radial inclination, volar tilt, and articular congruity is an important objective of operative treatment. These parameters help assess the quality of reduction and the maintenance of anatomical alignment during fracture healing. The illustrative results showed improvement in all three principal radiological measurements following fixation.

Volar locking plates are designed to maintain reduction through fixed-angle screw fixation, which can be advantageous in unstable fractures and fractures with metaphyseal comminution. However, careful assessment of screw length and plate position is essential to avoid intra-articular screw penetration, tendon irritation, and other implant-related complications.

Comparative systematic reviews have reported that volar locking plate fixation may provide better radiographic alignment than conservative treatment, although the differences in long-term patient-reported functional outcomes are often smaller than the radiographic differences[5,6]. This distinction is important because the principal objective of fracture treatment is not simply to achieve satisfactory radiographs but to restore useful, relatively pain-free function.

The illustrative union data showed that most patients achieved union within 12 weeks. In the final manuscript, fracture union should be documented using predefined clinical and radiological criteria. The mean time to union, variability, and proportion of patients with delayed union should be calculated from actual follow-up records. A six-month study period also requires careful interpretation because patients enrolled late in the recruitment period may have a shorter observation period than those enrolled earlier.

Postoperative Complications

The illustrative complication table identified wrist stiffness as the most frequent individual complication, followed by median nerve symptoms, tendon irritation, superficial wound infection, complex regional pain syndrome, and loss of reduction or malunion. These complications represent recognised concerns following distal radius fracture fixation.

Wrist stiffness may be associated with postoperative swelling, pain, immobilisation, or delayed rehabilitation. Median nerve symptoms may occur because of nerve compression or irritation associated with the injury or postoperative swelling. Tendon irritation or rupture may be related to plate prominence, screw protrusion, or tendon contact with the implant. Appropriate plate positioning, careful screw-length assessment, clinical monitoring, and timely recognition of symptoms are therefore important for minimising avoidable complications.

Published comparative evidence suggests that the complication profile of volar locking plate fixation depends on the comparator technique, fracture characteristics, and definitions used to record adverse events[5-7]. The presence of a complication does not necessarily indicate treatment failure, as some complications are transient and respond to conservative treatment, whereas others may require further surgery.

In the present study, complications should be reported by both event frequency and the number of unique patients affected. A patient may experience more than one complication, so adding individual event counts may overestimate the proportion of patients with

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complications. The overall complication rate should therefore be calculated using the number of patients who experienced at least one complication divided by the total number of patients assessed.

Relationship Between Fracture Type and Functional Outcome

The illustrative cross-tabulation showed that excellent or good outcomes occurred in 16 of 18 Type A fractures (88.9%), 9 of 10 Type B fractures (90.0%), and 16 of 22 Type C fractures (72.7%). This example suggests a possible trend towards less favourable functional outcomes in complete-articular fractures than in extra-articular or partial-articular fractures.

Such a pattern is clinically plausible because complete-articular fractures may involve greater comminution, more extensive articular disruption, and increased difficulty in restoring congruity. Nevertheless, fracture type alone cannot explain individual outcomes, and differences in the illustrative table must not be interpreted as statistically significant without formal analysis.

The association should be assessed using the chi-square test or Fisher's exact test, as appropriate. Because the sample comprises only 50 patients and some outcome categories contain small numbers, sparse expected cell counts may limit the validity of a conventional chi-square test. If required, categories may be combined only when clinically justified and specified before analysis, or an appropriate exact test may be used.

The AO/OTA classification is valuable for standardising fracture description, but its reproducibility and ability to predict individual outcomes are not absolute.[1] Therefore, the relationship between fracture classification and functional recovery should be considered exploratory in a study of this size.

Conclusion

Open reduction and internal fixation using volar locking plates is an effective surgical option for appropriately selected distal radius fractures, offering stable fixation and restoration of anatomical alignment. Functional recovery depends on fracture complexity, quality of reduction, and postoperative rehabilitation. Careful surgical technique and regular follow-up are essential to minimise complications and optimise clinical and radiological outcomes. Actual study data are required to establish the functional success rate and complication profile in the present cohort of 50 patients at GMC Solapur.

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