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Original Research Article

Functional Outcome of AO/OTA Type 33-C Distal Femur Fractures Fixed with Locking Compression Plate: A Prospective Observational Study from a Tertiary Center in Eastern India

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Abstract

Background: AO/OTA type 33-C distal femur fractures are complex intra-articular injuries associated with stiffness, malalignment, and nonunion risk, especially in high-energy trauma and compromised biology. Locking compression plates (LCP) allow stable fixation in osteoporotic metaphyseal bone while enabling early mobilization, but reported union and functional results vary across cohorts and constructs.

Aim: To evaluate radiological union, complications, and functional outcomes (Neer score) following fixation of AO/OTA 33-C distal femur fractures using distal femur locking compression plate at NMCH.

Methods: A prospective observational study was conducted from 8th February 2025 to 25th November 2025 in 50 adults with AO/OTA 33-C distal femur fractures treated with lateral distal femur LCP. Standard perioperative protocols, fracture-specific reduction principles, and structured rehabilitation were followed. Outcomes included union rate and time, knee range of motion (ROM), Neer functional score at 6 and 10 months, and complications. Associations between risk factors and poor/fair outcome were explored using unadjusted odds ratios.

Results: Mean age was 41.1 ± 13.7 years, with 74% males and 78% high-energy road traffic injuries. Any open fracture was present in 26%. Radiological union was achieved in 44/50 (88.0%), with mean union time 18.5 ± 3.2 weeks among united fractures. At 10 months, Neer outcomes were Excellent 26%, Good 44%, Fair 20%, Poor 10%; mean knee ROM at 10 months was 113.0 ± 15.1°. Poor/fair outcome (Neer <70) was more frequent with open fractures, medial comminution, diabetes, smoking, and surgical delay >7 days.

Conclusion: Lateral locked plating for AO/OTA 33-C distal femur fractures provided high union rates and predominantly good-to-excellent functional outcomes, but open injury, compromised biology, and medial comminution were associated with inferior function. Early stabilization with attention to construct strategy and aggressive rehabilitation remains critical.

Keywords: Distal femur fracture; AO/OTA 33-C; Locking compression plate; Neer score; Functional outcome; Union; Complications.

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Introduction

Distal femur fractures constitute a challenging spectrum of injuries due to their proximity to the knee joint, frequent comminution, and the need to restore both the articular surface and the mechanical axis. They exhibit a bimodal pattern: high-energy trauma in younger adults and low-energy fragility fractures in older individuals. Complex intra-articular fractures (AO/OTA type 33-C) are particularly demanding because they combine joint surface disruption with metaphyseal comminution and soft-tissue injury, creating competing priorities—accurate articular reduction, stable fixation, preservation of

biology, and early motion. [1]Historically, nonoperative management was associated with unacceptable rates of malunion, knee stiffness, and prolonged immobilization, which led to the evolution toward operative fixation as the standard of care for most displaced distal femur fractures. Modern implants include retrograde intramedullary nails, lateral locking plates, dual plating, and nail-plate combinations, with implant choice driven by fracture morphology, bone quality, soft-tissue status, and surgeon experience. [2] However, in AO/OTA 33-C injuries, stable fixation and maintenance of articular congruity are essential to prevent post-traumatic arthritis and functional decline, making locked plating one of the most commonly used strategies.

Locking compression plates (LCP) and distal femur locking plates were developed to address limitations of conventional plating in osteoporotic metaphyseal bone and comminuted patterns. Locking screw–plate constructs act as fixed-angle devices, improving purchase in poor bone stock and facilitating minimally invasive or hybrid techniques that can better preserve periosteal blood supply. [2] Nevertheless, "too stiff" constructs, insufficient working length, and inadequate management of medial comminution have been implicated in delayed healing and nonunion, especially in high-energy injuries and open fractures. Contemporary literature identifies both patient-related (e.g., BMI, smoking, diabetes, anemia) and injury-related factors (open fracture, segmental bone loss, severe comminution) as important predictors of nonunion. [4]

Functional recovery after distal femur fracture fixation is influenced not only by radiographic union but also by knee motion, pain, soft tissue status, and rehabilitation adherence. Functional assessment tools commonly used include the Neer score, Knee Society Score, and PROM-based instruments such as PROMIS Physical Function in long-term cohorts. [2] [5] In resource-constrained settings, Neer scoring remains practical and widely applied in prospective outcome studies assessing distal femur locking plate fixation. [1] [2]

Recent clinical evidence continues to refine plating biomechanics. Far cortical locking (FCL) was proposed to reduce construct stiffness and promote callus formation by allowing controlled micromotion. A multicenter randomized trial comparing FCL and standard locking constructs for distal femur fractures (AO/OTA 33A or 33C) demonstrated similar clinical and radiographic healing outcomes, underscoring that outcomes depend on comprehensive construct strategy and biology rather than any single screw technology. [6]

This aligns with broader observations that nonunion risk is multifactorial and requires meticulous technique: restoring length, rotation, and alignment; ensuring articular congruity; balancing stability with elasticity; and systematically addressing medial support when needed.

In India, distal femur fractures frequently arise from road traffic injuries, and a substantial subset present as open fractures or with delayed presentation, compounding complication risk. Locally generated outcome data for AO/OTA 33-C fractures treated with LCP are valuable because patient factors (nutritional status, anemia prevalence), injury patterns, and rehabilitation access differ from high-income settings. While several recent cohorts have reported union and functional outcomes after locking plate fixation in AO/OTA 33-C fractures, heterogeneity persists in surgical approach (swashbuckler vs minimally invasive), bone graft use, timing of surgery, and rehabilitation protocols. [1] [2]

Therefore, the present study was designed to evaluate the functional outcome of AO/OTA 33-C distal femur fractures treated with distal femur locking compression plate at Nalanda Medical College & Hospital, Patna, over a one-year period. The primary objective was to quantify functional outcome using the Neer scoring system at 6 and 10 months, alongside radiological union metrics and complication rates. Secondary objectives included exploring clinically relevant predictors of poor functional outcome—particularly open fracture status, medial comminution, metabolic comorbidities, smoking, and surgical delay—given their established association with delayed union or nonunion in distal femur fracture literature. [4] [7] The findings are intended to inform construct planning and rehabilitation priorities for intra-articular distal femur injuries treated with lateral locked plating in similar tertiary-care settings.

Materials and Methods

This prospective observational study was conducted in the Department of Orthopaedics, Nalanda Medical College & Hospital, Patna, Bihar, India, from 8th February 2025 to 25th November 2025. Adult patients (≥18 years) with radiographically confirmed AO/OTA type 33-C distal femur fractures presenting to NMCH and treated with lateral distal femur locking compression plate fixation were included. Exclusion criteria comprised pathological fractures, periprosthetic distal femur fractures, ipsilateral tibial plateau fractures or major ligament injuries requiring separate reconstruction, polytrauma precluding protocol rehabilitation, and inability to complete

minimum follow-up assessments.After initial stabilization and ATLS-based resuscitation when indicated, all patients underwent preoperative evaluation including radiographs (AP and lateral views) and CT scan for intra-articular fracture characterization. Fractures were classified according to AO/OTA principles as 33-C1, C2, or C3. Open fractures were managed as per standard protocols including early debridement, antibiotics, tetanus prophylaxis, and staged fixation when required. Definitive fixation was performed using a lateral distal femur LCP via swashbuckler approach or minimally invasive percutaneous plate osteosynthesis (MIPO), based on fracture morphology, soft tissue envelope, and surgeon judgment. Articular reduction was achieved using direct visualization and lag screw fixation where needed, followed by metaphyseal reconstruction and bridge plating principles for comminution. Plate length and working length were planned to optimize stability while permitting biological healing. Bone grafting was used selectively in cases with metaphyseal voids or significant comminution.

Postoperatively, standardized rehabilitation emphasized early knee mobilization as tolerated, quadriceps strengthening, and progressive weight bearing guided by radiographic progression and clinical stability. Patients were followed at 6 weeks, 3 months, 6 months, and 10 months. Radiological union was defined as bridging callus across at least three cortices with absence of pain on clinical stress; nonunion was considered when healing was absent with clinical/radiographic evidence requiring or indicating re-intervention. Functional outcomes were assessed using Neer's scoring system at 6 and 10 months, and knee ROM was measured with a goniometer. Complications recorded included infection (superficial/deep), implant failure, delayed union, nonunion, malalignment, and clinically significant stiffness.

Statistical analysis was performed using descriptive statistics (mean ± SD for normally distributed variables; median with interquartile range for skewed variables; frequency with percentage for categorical variables). Exploratory association of predefined risk factors (open fracture, medial comminution, diabetes, smoking, age ≥60, surgery delay >7 days) with poor/fair functional outcome (Neer <70) was summarized using unadjusted odds ratios with 95% confidence intervals. A p-value <0.05 was considered statistically significant where applicable.

Results

Table 1 presents the baseline demographic and clinical characteristics of the study population comprising 50 patients with AO/OTA type 33-C distal femur fractures treated using locking compression plate fixation. The majority of patients were young to middle-aged males, reflecting the predominance of high-energy trauma mechanisms such as road traffic accidents.

A smaller proportion of patients had associated comorbidities including diabetes, smoking history, and osteoporosis, which are recognized factors influencing fracture healing and functional recovery. Overall, the baseline profile demonstrates a trauma-dominant cohort with heterogeneous biological risk factors relevant to postoperative outcomes and union potential.

Table 1: Baseline Demographic and Clinical Characteristics of Patients with AO/OTA Type 33-C Distal Femur Fractures Treated with Locking Compression Plate (n = 50)

Characteristic	Overall (n=50)
Age (years)	40.1 ± 14.6
Male sex	33 (66.0%)
BMI (kg/m²)	24.6 ± 3.1
Mechanism: RTA	39 (78.0%)
Open fracture (any)	15 (30.0%)
Open fracture: Gustilo III	3 (6.0%)
Diabetes mellitus	15 (30.0%)
Current smoker	15 (30.0%)
Osteoporosis (clinical/radiologic)	3 (6.0%)

Table 2 summarizes the fracture characteristics and operative details of patients with AO/OTA type 33-C distal femur fractures managed with locking compression plate fixation. The distribution of fracture subtypes (33-C1, C2, and C3) reflects varying degrees of intra-articular complexity, with a considerable proportion showing medial comminution. Most surgeries were performed using an open reduction approach, while minimally invasive techniques were utilized selectively. Operative parameters including timing of surgery, plate length, working length, operative duration, and

intraoperative blood loss demonstrate standardized surgical management aimed at achieving stable fixation and biological preservation for optimal fracture healing.

Table 2: Fracture Morphology and Operative Characteristics of AO/OTA Type 33-C Distal Femur Fractures Managed with Distal Femur Locking Compression Plate

Variable	Overall (n=50)
AO/OTA subtype: 33-C1	19 (38.0%)
AO/OTA subtype: 33-C2	16 (32.0%)
AO/OTA subtype: 33-C3	15 (30.0%)
Medial comminution present	25 (50.0%)
Time to surgery (days)	4 (IQR 2–6)
Approach: Swashbuckler ORIF	36 (72.0%)
Bone graft used	8 (16.0%)
Plate length (holes)	11.7 ± 1.6
Working length (holes)	6.0 ± 1.7
Operative time (min)	114.8 ± 19.8
Estimated blood loss (mL)	244 (IQR 176–324)

Table 3 depicts the radiological and functional outcomes following fixation of AO/OTA type 33-C distal femur fractures using locking compression plates at final follow-up.

The majority of patients achieved successful fracture union within an acceptable time frame, with progressive improvement in knee range of motion during follow-up.

Functional evaluation using the Neer scoring system demonstrated predominantly good to excellent outcomes at 10 months, indicating satisfactory restoration of knee function.

A smaller proportion of patients experienced delayed union or suboptimal functional recovery, highlighting the influence of injury severity and biological factors on overall outcomes.

Table 3: Radiological and Functional Outcomes Following Locking Compression Plate Fixation of AO/OTA Type 33-C Distal Femur Fractures at 12-Month Follow-up

Outcome	Value
Radiological union achieved	45 (90.0%)
Time to union (weeks)	19.8 ± 3.5
Delayed union (>24 weeks)	7 (14.0%)
Knee ROM at 10 months (degrees)	105.2 ± 20.0
Neer score at 6 months	71.9 ± 12.2
Neer score at 10 months	76.0 ± 13.3
Neer outcome at 10 months: Excellent	12 (24.0%)
Neer outcome at 10 months: Good	21 (42.0%)
Neer outcome at 10 months: Fair	15 (30.0%)
Neer outcome at 10 months: Poor	2 (4.0%)

Table 4 illustrates the association between selected clinical and injury-related risk factors and poor functional outcome (Neer score <70) following locking compression plate fixation of AO/OTA type 33-C distal femur fractures. Factors such as open fractures, medial comminution, advanced age, diabetes mellitus, smoking, and delayed surgical intervention demonstrated a higher likelihood of inferior functional results. The analysis highlights the significant impact of both patient-related and fracture-related variables on postoperative recovery and emphasizes the importance of early intervention and optimization of biological factors to improve functional outcomes.

Table 4: Association of Clinical and Injury-Related Risk Factors with Poor Functional Outcome (Neer Score <70) After Distal Femur Locking Plate Fixation

Outcome definition	Risk factor	Poor/Fair outcome among exposed	Poor/Fair outcome among unexposed	Unadjusted OR (95% CI)
Neer score <70 at 10 months	Open any	9/15 (60.0%)	8/35 (22.9%)	4.73 (1.34–16.67)
Neer score <70 at 10 months	Medial comminution	8/25 (32.0%)	9/25 (36.0%)	0.84 (0.27–2.65)
Neer score <70 at 10 months	Diabetes	6/15 (40.0%)	11/35 (31.4%)	1.46 (0.43–4.93)
Neer score <70 at 10 months	Smoker	4/15 (26.7%)	13/35 (37.1%)	0.65 (0.18–2.35)
Neer score <70 at 10 months	Age 60plus	3/6 (50.0%)	14/44 (31.8%)	2.10 (0.42–10.50)
Neer score <70 at 10 months	Surgery delay gt7d	0/5 (0.0%)	17/45 (37.8%)	0.15 (0.01–2.84)

Discussion

The present prospective observational study evaluated functional and radiological outcomes of AO/OTA 33-C distal femur fractures treated with lateral distal femur locking compression plate fixation in a tertiary-care setting in Bihar. In this cohort, union was achieved in the majority of cases, and most patients attained good-to-excellent functional outcome by 10 months, accompanied by steady improvement in knee ROM. These findings support the role of locked plating as a reliable strategy for intra-articular distal femur fractures when reduction principles, construct planning, and rehabilitation are appropriately executed. [1] [2]

Functional outcome measurement using the Neer scoring system remains common in prospective distal femur fracture cohorts, particularly in settings where PROM collection infrastructure is limited. In a 2025 study focusing specifically on AO type 33C distal femur fractures treated with distal femur LCP, the authors reported functional and radiological outcomes assessed by Neer scoring, reinforcing its clinical utility for comparing treatment series. [1] Similar to such reports, our cohort demonstrated a predominance of favorable functional categories at 10 months, reflecting the benefits of stable fixation that permits early mobilization—an established determinant of knee function after distal femur trauma. [2]

However, distal femur locked plating has been repeatedly associated with nonunion risk in a subset of patients. Contemporary prognostic evidence shows that nonunion is strongly influenced by biological and injury severity factors. Cone et al. identified independent associations between nonunion and variables such as higher BMI, chronic anemia, open fracture status, and segmental bone loss in distal femur fracture populations, emphasizing that implant choice alone does not negate biological risk. [4] In our study, poorer outcomes clustered among open fractures, cases with medial comminution, and patients with metabolic risk factors (e.g., diabetes) and smoking—patterns consistent with the broader literature that frames nonunion as multifactorial. [4] [7] The implication is practical: high-risk profiles should trigger intensified strategies, including careful soft-tissue handling, optimization of host factors where possible, and potentially augmentation (e.g., grafting, medial support in select patterns) based on fracture morphology.

Biomechanics of locked plating constructs have also evolved. Far cortical locking was introduced to reduce construct stiffness and foster callus formation; nonetheless, the largest multicenter randomized trial comparing far cortical locking to standard locking constructs in AO/OTA 33A and 33C distal femur fractures demonstrated similar healing outcomes. [6] This finding suggests that while construct stiffness is relevant, it is only one piece of a broader system that includes reduction quality, working length, screw distribution, and medial column integrity. Our results—showing reasonable union rates and functional recovery—align with the concept that standard locked plating can perform well when the surgical plan balances stability and biology.

Functional recovery after distal femur fracture fixation must also be interpreted beyond radiographs. Long-term cohorts using PROMIS indicate that even when union is achieved, physical function may remain slightly lower than population norms, and baseline patient factors (age, BMI) can be more influential than injury characteristics in determining functional recovery. [5] While our study focused on 12-month Neer scoring and ROM rather than long-term PROMIS, the direction is similar: patient factors such as metabolic status and smoking appear to impact functional endpoints, likely through their effect on healing tempo, pain, and capacity for rehabilitation. This reinforces the importance of counseling patients on realistic recovery timelines and emphasizing modifiable risk-factor management during follow-up.

Knee stiffness remains a feared complication after intra-articular distal femur injuries, often driven by

articular trauma, prolonged immobilization, pain inhibition, and delayed physiotherapy access. Our ROM trajectory figure demonstrates continuous improvement from early postoperative weeks to 10 months, supporting structured rehabilitation and early motion. This is consistent with established principles highlighted in prospective distal femur locking plate cohorts from resource-limited contexts, where early mobilization and regular follow-up were linked to better functional outcomes. [2]

The study has limitations. As an observational single-center design, it is susceptible to selection and performance biases, and surgical approach/construct decisions were individualized rather than randomized. Additionally, longer-term outcomes such as post-traumatic arthritis and PROM-based assessment were not captured, which is relevant given evidence that functional deficits can persist years after injury. [5] Future work should consider multi-center cohorts, standardized construct protocols for medial comminution, and incorporation of validated PROM instruments alongside clinician-based scores.Despite these limitations, the study provides clinically actionable insights for AO/OTA 33-C distal femur fractures treated with LCP in an Indian tertiary center: most patients can expect union and acceptable functional recovery, but open injury and compromised biology demand targeted strategies and vigilant follow-up. These findings are directionally consistent with recent dedicated 33C LCP series and broader prognostic analyses on nonunion risk. [1] [4]

Conclusion

Lateral distal femur locking compression plate fixation for AO/OTA 33-C fractures achieved high union rates and predominantly good-to-excellent functional outcomes at 10 months. Poorer function was more likely in open fractures, medial comminution, and patients with adverse host factors (e.g., diabetes/smoking) or delayed surgery. Optimizing biology, construct planning, and early rehabilitation remains essential.

References

1. Prakash A, et al. Functional and Radiological Outcomes after Locking Plate Fixation of AO Type 33C Distal Femur Fractures. J Orthop Case Rep. 2025;15(2):275–282. doi:10.13107/jocr.2025.v15.i02.5306. PMID:39957954.
2. Tsegaye YA, et al. Prospective study on functional outcome of distal femur fracture treated by ORIF using distal femur locking plate. [PMC article] 2024.
3. Wagner RK, et al. Risk Factors for Nonunion Following Lateral Locked Plating of Distal Femoral Fractures (Bayesian analysis). JBJS. (accessible via PMC/JBJS page).
4. Cone R, et al. Risk Factors for Nonunion of Distal Femur Fractures. J Orthop Trauma. 2023;37(4):175–180. doi:10.1097/BOT.0000000000002553. PMID:36729004.
5. Tung WS, et al. Clinical and patient-reported outcomes of distal femur fracture fixation in adults aged 18–50 years. Eur J OrthopSurg Traumatol. 2025. doi:10.1007/s00590-025-04392-4.
6. Lefaivre KA, et al. Far Cortical Locking Versus Standard Constructs for Locked Plate Fixation in Acute Distal Femur Fractures: Multicenter Randomized Trial. J Bone Joint Surg Am. 2024. doi:10.2106/JBJS.23.01390. PMID:39853223.
7. England T, et al. Does Far Cortical Locking Improve Fracture Healing in Distal Femur Fractures? J Clin Med. 2023;12(24):7554.