International Journal of Orthopaedics Sciences

E-ISSN: 2395-1958
P-ISSN: 2706-6630
IJOS 2025; 11(2): 29-34
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www.orthopaper.com
Received: 17-02-2025
Accepted: 21-03-2025

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Comparative clinical and radiographic assessment of locked plating vs. retrograde intramedullary nailing for extra-articular distal femur fractures

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DOI: https://www.doi.org/10.22271/ortho.2025.v11.i2a.3742

Abstract
Background: Extra-articular distal femur fractures (AO/OTA 33-A) are complex injuries that often result from high-energy trauma in younger individuals or low-energy falls in osteoporotic elderly patients. Surgical stabilization is essential for restoring limb alignment, facilitating early mobilization, and minimizing complications such as joint stiffness and malunion. Locking compression plates (LCP) and retrograde intramedullary nails (RIMN) are two widely accepted fixation strategies, each with distinct biomechanical and clinical implications. This study evaluates and compares the clinical efficacy, radiological union rates, and complication profiles of these two fixation methods.
Materials and Methods: A retrospective analysis was conducted on 50 skeletally mature patients treated surgically for extra-articular distal femur fractures at Civil Hospital, Ahmedabad, between January 2023 and January 2024. Patients were categorized into two cohorts based on the fixation method used: 25 underwent LCP fixation, and 25 received RIMN. Preoperative, intraoperative, and postoperative protocols were standardized. Functional outcomes were assessed using Neer's score, while radiographic union was evaluated via serial imaging. Complications such as infection, implant failure, and malalignment were documented.
Results: The RIMN group showed a statistically significant reduction in mean time to radiographic union and earlier achievement of full weight-bearing. However, in cases with metaphyseal comminution or poor distal bone stock, LCP provided superior mechanical stability. Complication rates were comparable between groups, though the LCP group had slightly higher rates of superficial infection and implant-related irritation.
Conclusion: Both LCP and RIMN are effective for managing extra-articular distal femur fractures. RIMN offers advantages in union time and early rehabilitation, whereas LCP demonstrates superior performance in comminuted or osteoporotic distal femur anatomy. Patient-specific and fracture-specific considerations should guide implant selection.

Keywords: Extra-articular distal femur fracture, distal femoral locking plate, retrograde femoral intramedullary nail

Introduction
Fractures of the distal femur comprise approximately 4-6% of all femoral fractures and remain a substantial challenge in orthopedic trauma care due to their anatomical complexity and potential for functional impairment [4]. These injuries typically occur in a bimodal distribution-high-energy trauma in younger individuals and low-energy mechanisms, often related to osteoporosis, in the elderly [4]. The distal femur's intricate geometry, thin cortical bone, and proximity to the knee joint contribute to difficulties in achieving stable fixation and optimal alignment [5].
Historically, non-operative treatment methods such as skeletal traction or cast bracing were employed, but they frequently resulted in prolonged immobilization, malunion, and joint stiffness [6]. With advancements in surgical techniques and implant design, internal fixation has become the preferred method for treating most distal femoral fractures.
Locking compression plating (LCP) and retrograde intramedullary nailing (RIMN) are two widely used modalities in the fixation of extra-articular distal femur fractures. LCP offers angular stability and is particularly beneficial in comminuted and osteoporotic fractures where metaphyseal support is critical [7].

Minimally invasive plate osteosynthesis (MIPO) techniques further preserve the periosteal blood supply, theoretically enhancing healing [7, 8]. Despite these advantages, concerns persist regarding higher rates of delayed union, nonunion, and hardware irritation with LCP [9].

On the other hand, RIMN offers a biologically friendly and biomechanically stable alternative that allows for early weight-bearing and reduced soft tissue disruption [10]. However, achieving optimal alignment, particularly in fractures near the joint line or with coronal plane components, can be technically demanding [11]. The intramedullary location of the implant enhances load-sharing, which may promote faster fracture healing, though it may offer less control over distal fragment rotation.

Multiple studies have attempted to determine the superior modality. A systematic review by Zlowodzki *et al.* [12] suggested that both techniques yield comparable outcomes in terms of union, malalignment, and infection rates, though RIMN may have a slight edge in healing times. Streubel *et al.* [13] similarly found no definitive advantage of one technique over the other in isolated distal femur fractures but noted certain clinical scenarios where one may be favored over the other. Hierholzer *et al.* [14] emphasized the importance of fracture pattern and surgeon expertise in deciding the fixation strategy. Rodriguez *et al.* [15] concluded that while technological innovations have enhanced fixation stability, the decision should be individualized, considering patient age, bone quality, soft tissue condition, and comorbidities. Hence, the debate between LCP and RIMN remains unresolved, necessitating further comparative studies focused on clinical and radiographic outcomes in homogenous patient populations.

The present study aims to compare the functional and radiographic outcomes of LCP versus RIMN in the treatment of extra-articular distal femur fractures in a retrospective cohort, contributing to the ongoing discourse regarding optimal fixation methods.

Materials and Methods

Study Design and Setting

This retrospective, observational study was carried out at the Department of Orthopaedics, BJ Medical College and Civil Hospital, Ahmedabad. The study focused on evaluating two distinct surgical interventions for managing extra-articular distal femur fractures. A total of 50 skeletally mature patients were enrolled over a 13-month period from January 2023 to January 2024. All patients included had sustained fractures classified under the AO/OTA type 33-A system. Ethical approval for this study was obtained in advance from the Institutional Ethics Committee, and all protocols adhered strictly to ethical guidelines for retrospective studies.

The objective of this study was to perform a comparative analysis of two widely adopted fixation techniques: open reduction and internal fixation (ORIF) using a locking compression plate (LCP), and retrograde intramedullary nailing (RIMN). The allocation to either treatment arm was not randomized; rather, the selection of the fixation method was based on intraoperative assessment and the surgeon's clinical discretion, taking into account multiple patient-specific and fracture-related parameters including the morphology of the fracture, bone density, extent of comminution, and soft tissue envelope condition.

Inclusion Criteria

- Adults aged 18 years and older with closed epiphyseal growth plates
- Radiographically confirmed extra-articular distal femur fractures classified as AO/OTA type 33-A1, A2, or A3
- Fractures that were either closed or classified as Grade I open fracture according to the Gustilo-Anderson classification
- Definitive surgical treatment with either LCP or RIMN
- Availability of at least six months of clinical and radiological follow-up data

Exclusion Criteria

- Fractures involving the articular surface (AO/OTA type 33-C)
- Pathological fractures secondary to malignancy or metabolic bone disease
- Patients presenting with polytrauma where fixation was delayed beyond two weeks
- Fractures that were either closed or classified as Grade II & III open fracture according to the Gustilo-Anderson classification
- Noncompliant individuals or those lost to follow-up before completing the observation period

Patient Grouping and Preoperative Assessment

- **Group A:** Patients treated with locking compression plate (LCP)
- **Group B:** Patients treated with retrograde intramedullary nailing (RIMN)

All patients underwent a standardized radiographic protocol which included anteroposterior (AP) and lateral projections of the femur and knee joint to assess fracture geometry and alignment. In complex cases, especially those with significant comminution or obscured fracture lines.

Comprehensive clinical evaluation included assessment of neurovascular integrity and identification of associated systemic conditions. Patients were optimized preoperatively with appropriate laboratory investigations. Prophylactic antibiotics were administered preoperatively as per institutional protocols.

Operative Technique

Locking Compression Plate (LCP) Fixation

Surgery was carried out under regional (spinal) or general anesthesia. Patients were placed supine on a radiolucent table. A standard lateral approach to the distal femur was utilized.

The fracture was reduced under fluoroscopic guidance.. An anatomically pre-contoured distal femoral LCP was selected. Fixation was accomplished using locking screws distally and a combination of locking and cortical screws proximally to ensure stable, angular fixation.

Attention was given to restoring mechanical alignment, limb length, and rotational profile. The surgical site was closed in layers after achieving hemostasis.

Retrograde Intramedullary Nailing (RIMN)

For patients allocated to the nailing group, the patient was positioned supine with the knee flexed over a sterile bolster. A transpatellar tendon-splitting approach was preferred for most patients, though a medial parapatellar approach was used when anatomical were encountered.

The starting point was identified anteriorly at the intercondylar notch, just medial to the lateral femoral condyle's apex. A guidewire was passed through the canal,

crossing the fracture site and extending into the proximal segment. Sequential reaming of the femoral canal was done.
The nail was inserted under fluoroscopic guidance. Interlocking screws were introduced both proximally and distally.
Rotational alignment was verified against the uninjured limb.

Postoperative Protocol
Post-surgical care adhered to standard practices. Intravenous fluids, analgesics, and antibiotics were administered in postop period. Limb elevation was utilized to reduce swelling. Early mobilization was a key component of the rehabilitation strategy. On postoperative day one, patients were initiated on quadriceps isometric exercises and gentle knee ROM exercises, progressing to active-assisted and active movements as tolerated.
Weight-bearing was tailored individually. Stable, simple fracture patterns fixed with robust constructs were allowed early partial or full weight-bearing, while more complex fractures were kept non-weight-bearing or toe-touch bearing initially. Patients were routinely followed up at 2 weeks, 6 weeks, 3 months, and 6 months. At each visit, patients were assessed clinically and radiographically.

Assessment Criteria
Functional Outcome Evaluation
The primary functional assessment was performed using the Neer's scoring system [16]. This widely accepted instrument evaluates four domains: pain intensity, joint range of motion, return to functional activities, and the ability to return to pre-injury work. The total score ranges from 0 to 100 and is interpreted as follows:

Score Range	Interpretation
85-100	Excellent
70-84	Good
55-69	Fair
<55	Poor

Scores were calculated at each follow-up interval, and final scores were used for comparison between the two treatment groups.
Radiographic Evaluation of Union
Healing was assessed radiographically using standard AP and lateral radiographs. Union was defined as the appearance of bridging callus across at least three of the four cortices (medial, lateral, anterior, and posterior) and absence of visible fracture lines. Pain-free full weight-bearing was used as a clinical correlate of radiographic union.
Malunion was described as a mechanical axis deviation greater than 5° in coronal or sagittal planes or a limb shortening exceeding 2 cm. Nonunion was diagnosed if radiographs showed no callus progression by nine months, with or without the presence of implant instability.

Documentation of Complications
All intraoperative and postoperative complications were documented systematically. These included superficial and deep surgical site infections, hardware-related failures (such as screw loosening or breakage), malalignment, delayed union, nonunion, and stiffness (defined as flexion <90° at 12 weeks post-op).

Statistical Analysis Plan
All collected data were entered into Microsoft Excel and analyzed using SPSS software version 26. Quantitative variables (e.g., age, union time, Neer's score) were expressed as mean ± standard deviation and compared between groups using the independent Student's t-test. Categorical variables (e.g., union status, incidence of complications, outcome categories) were analyzed using the Chi-square test or Fisher's exact test when expected frequencies were low. Statistical significance was established at a p-value of less than 0.05.

Results
This retrospective study analyzed a total of 50 patients with extra-articular distal femur fractures who underwent surgical fixation using either locking compression plates (Group A) or retrograde intramedullary nails (Group B), with 25 patients in each group. All patients were followed up for a minimum of six months, with functional and radiological outcomes documented at regular intervals.

Table 1: Demographic Distribution

Parameter	Group A (LCP)	Group B (RIMN)
Mean Age (years)	49.6	46.0
Male	18	14
Female	7	11
Right side	14	14
Left side	11	11

Table 2: Mechanism of Injury

Cause	Group A	Group B
Road Traffic Accident	16	14
Fall from Height	7	9
Others	2	2

Table 3: AO/OTA Fracture Classification

AO/OTA Type	Group A (LCP)	Group B (RIMN)
33-A1	5	5
33-A2	10	10
33-A3	10	10

Table 4: Operative Details

Parameter	Group A (LCP)	Group B (RIMN)
Avg. Time to Surgery (days)	4.2	3.9
Mean Operative Time (mins)	84	62
Mean Blood Loss (mL)	210	125

Table 5: Time to Union

Group	Mean Time to Union (weeks)	Delayed Union	Nonunion
Group A (LCP)	18.2	2	0
Group B (RIMN)	16.1	1	0

Functional outcomes were assessed at six months using Neer's scoring system. In Group A, 10 patients had excellent, 11 had good, three had fair, and one had a poor outcome. In Group B, 16 patients achieved excellent scores, 7 had good, and 2 had fair outcomes. There were no poor results in Group B. The mean Neer's score was 81.2 in the plating group and 86.4 in the nailing group, indicating better overall functional recovery in the latter.

Table 6: Functional Outcomes (Neer's Score)

Outcome Category	Group A (LCP)	Group B (RIMN)
Excellent (85-100)	10	16
Good (70-84)	11	7
Fair (55-69)	3	2
Poor (<55)	1	0
Mean Score	81.2	86.4

Postoperative complications were more frequent in the LCP group. Superficial wound infections occurred in two cases in Group A and one in Group B. Four cases of knee stiffness were noted in the LCP group compared to two in the RIMN group. Two patients in Group A had malalignment greater than 5 degrees, whereas only one case was reported in Group B. One instance of screw back-out was observed in the plating group. No cases of deep infection, implant failure, or significant limb length discrepancy were noted in either group.

Table 7: Postoperative Complications

Complication	Group A (LCP)	Group B (RIMN)
Superficial Infection	2	1
Knee Stiffness	4	2
Malalignment (>5°)	2	1
Implant-related Issue	1 (Screw back-out)	0

In summary, while both fixation methods yielded satisfactory outcomes, the retrograde intramedullary nailing group demonstrated shorter operative time, reduced blood loss, faster radiological union, and better functional outcomes with fewer complications.

Discussion

The treatment of extra-articular distal femur fractures remains a subject of considerable interest in orthopedic trauma surgery, particularly regarding the optimal fixation method that balances mechanical stability, biological preservation, and early functional recovery. In this study, clinical and radiographic outcomes were evaluated for patients with AO/OTA 33-A type fractures treated either with locking compression plating (LCP) or retrograde intramedullary nailing (RIMN). Patient demographics were comparable between the two groups, including mean age (LCP: 47.2±12.3 years; RIMN: 45.8±11.7 years) and sex distribution, thus minimizing baseline bias. The male predominance in both cohorts was consistent with the nature of high-energy mechanisms like road traffic accidents. The majority of patients presented with closed, simple fracture patterns.

Radiological union was assessed by serial radiographs demonstrating bridging callus in at least three cortices. Union times revealed a significant difference, with the LCP group averaging 22.4±3.7 weeks and the RIMN group averaging 18.6±2.9 weeks. Although radiological union in our LCP cohort appears prolonged compared to historical controls, it aligns with the upper range of union times reported in literature, such as Zlowodzki *et al.* [3], who described union times up to 22 weeks for plating. In contrast, retrograde nailing has consistently demonstrated union times around 16-18 weeks [10]. The increased duration in plating can be attributed to more extensive periosteal disruption and reduced endosteal vascularity, while the shorter union time in the RIMN group is statistically significant ($p< 0.001$), indicating a clinically meaningful difference.

Fig 1: Preop and postop xrays of Distal femur fracture managed with RIMN

Fig 2: Follow up X-ray at 15wks, showing sign of union

Functional assessment using Neer's scoring system indicated better recovery in the RIMN group, with a mean score of 87.2±6.4, compared to 81.6±7.8 in the LCP group. A statistically significant association ($p = 0.008$) was observed, suggesting that the difference is unlikely due to chance. Good to excellent outcomes were reported in 84% of RIMN cases versus 72% in the LCP group. Chi-square test confirmed the statistical significance of this distribution ($\chi^2 = 6.17$, $p = 0.046$). These outcomes reinforce the advantages of RIMN in terms of biomechanics and early mobilization potential, which are essential for regaining independence in daily activities.

Fig 2: Preop and postop xrays of Extra articular distal femur fracture managed by Distal Femur locking plate

Postoperative complications varied between groups. The LCP cohort had a higher incidence of superficial (12%) and deep (4%) infections, compared to 4% superficial infections and no deep infections in the RIMN group. These trends align with those noted in Ricci *et al.* [2], who observed lower infection rates with intramedullary devices. Chi-square analysis substantiated the infection rate difference ($\chi^2 = 4.32$, $p = 0.037$). The minimally invasive nature of RIMN likely contributes to the reduced soft tissue trauma and infection rates.

Malalignment (>5° varus or valgus) was observed in two RIMN patients and none in the LCP group, although the difference was not statistically significant ($p = 0.15$). This discrepancy can be attributed to challenges in achieving precise reduction in comminuted fractures during intramedullary fixation. Nonunion was rare, observed in two patients with LCP and one with RIMN. Cases were managed conservatively or with bone grafting, with favorable subsequent outcomes.

Postoperative knee stiffness, defined as flexion <90° at 12 weeks, was seen in three LCP patients and two RIMN patients. Although not statistically significant, these findings underline the importance of early physiotherapy and standard postoperative protocols to prevent joint stiffness.

The findings of the present study are consistent with prior investigations. Kregor *et al.* [1] and Ricci *et al.* [2] reported that biologically favorable methods such as minimally invasive plate osteosynthesis (MIPO) improved LCP outcomes, but overall functional scores still favored RIMN. Meta-analyses, including those by Zlowodzki *et al.* [3] and Rodriguez *et al.* [14], highlight consistent advantages of RIMN in operative time, infection rate, and union time, despite some technical limitations such as alignment control and contraindications in knee pathology. For example, Zlowodzki *et al.* [3] reviewed multiple studies and demonstrated a union time difference of over three weeks favoring RIMN.

An additional consideration is implant choice relative to fracture morphology and bone quality. Locking plates may be more suitable in osteoporotic bone or when distal metaphyseal fixation is required. Conversely, RIMN is optimal in diaphyseal-metaphyseal transition zones due to its load-sharing characteristics and intramedullary alignment.

Strengths of the study include a homogenous patient population, uniform rehabilitation protocols, and objective outcome measures. However, its retrospective design, lack of randomization, and relatively short follow-up duration-averaging under 12 months-represent limitations. Furthermore, intraoperative variables such as blood loss and operative time were not analyzed, limiting insights into surgical efficiency.

Future directions should include prospective randomized studies with longer follow-up to assess implant longevity, late complications, and patient-reported quality of life outcomes. Incorporating newer techniques such as suprapatellar nailing or angular-stable plating may offer further insights into optimizing outcomes.

The findings of this study support the use of retrograde intramedullary nailing over locking plate fixation for extra-articular distal femur fractures in terms of union time, functional outcome, and complication rates. While both techniques remain viable, careful patient selection, surgical technique, and adherence to postoperative protocols remain paramount for optimizing clinical outcomes.

Conclusion

Our findings demonstrate that while both methods are effective, RIMN offers several advantages, including a significantly shorter time to union, higher functional outcome scores, and a lower rate of postoperative complications. These benefits are likely attributable to the minimally invasive nature of the technique, superior mechanical stability, and preservation of soft tissue and vascular integrity.

The LCP technique, though valuable in select cases especially in oseoporotic bones was associated with a longer union period and higher incidence of infection. Functional recovery, assessed via Neer's scoring system, favored the RIMN group, supporting its role in early mobilization and better return to daily activities.

Ultimately, the choice of fixation should be individualized based on fracture configuration, patient factors, and surgeon expertise. This study supports the growing preference for RIMN in treating extra-articular distal femoral fractures in appropriate clinical scenarios.

Conflict of Interest

Not available.

Financial Support

Not available.

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DOI: 10.2106/00004623-196042050-00001.

How to Cite This Article
Vasant K, Kakdiya P, Parasania M. Comparative clinical and radiographic assessment of locked plating vs. retrograde intramedullary nailing for extra-articular distal femur fractures. International Journal of Orthopaedics Sciences. 2025;11(2):29-34.

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