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COMPARATIVE ANALYSIS OF RETROGRADE INTRAMEDULLARY NAILING AND LOCKING PLATE FIXATION IN EXTRA-ARTICULAR DISTAL FEMUR FRACTURES: A PROSPECTIVE OBSERVATIONAL STUDY

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ABSTRACT

Background: Extra-articular distal femur fractures are challenging orthopedic injuries that require stable fixation to enable early mobilization and functional recovery. While locking compression plates (LCP) and distal femoral nails (DFN) are both widely used surgical options, there remains ongoing debate regarding their relative efficacy in terms of clinical and radiological outcomes.
Aim: To compare the functional, radiological, and rehabilitative outcomes of retrograde intramedullary nailing versus locking plate fixation in the treatment of extra-articular distal femur fractures.
Materials and Methods: This prospective observational study was conducted at the Department of Orthopaedics, J.A. Group of Hospitals, Gwalior. A total of 40 adult patients with AO type 33-A distal femur fractures were randomly assigned to receive either retrograde intramedullary nailing (DFN, n=20) or distal femoral locking plate fixation (LCP, n=20). Patients were followed for 12 months postoperatively. Outcome measures included knee flexion, time to full weight-bearing, Neer score, total anatomical score, and complication profile. Statistical comparisons were made using Student's t-test and chi-square test.
Results: The DFN group demonstrated significantly shorter operative time (76.1 ± 7.8 vs 105.4 ± 9.9 minutes; $p<0.001$) and earlier weight-bearing (16.6 ± 3.6 vs 26.1 ± 3.8 weeks; $p<0.001$). DFN also showed superior knee flexion (17.6 ± 2.4 vs 12.6 ± 4.0; $p<0.001$), higher Neer scores (83.1 ± 11.3 vs 73.7 ± 16.2; $p=0.012$), and better anatomical alignment. While complication rates were comparable, DFN patients experienced better outcomes even in the presence of complications.
Conclusion: Retrograde intramedullary nailing offers superior functional and radiological outcomes compared to locking plate fixation in extra-articular distal femur fractures, with the added advantages of earlier rehabilitation and greater complication resilience. It should be considered the preferred technique when anatomically and clinically appropriate.
Keywords: Distal femur fracture; retrograde intramedullary nailing; locking compression plate; functional outcome; orthopedic fixation.

INTRODUCTION

Distal femur fractures represent complex injuries that involve the metaphyseal region between the diaphysis and the articular surface of the femur. These fractures often result from high-energy trauma in younger individuals or low-energy falls in the elderly, frequently associated with osteoporotic bone.[1] Extra-articular distal femoral fractures, particularly those classified under AO/OTA type 33-A, do not extend into the knee joint but nonetheless

present substantial challenges in achieving stable fixation due to the wide medullary canal, thin cortical bone, and muscular deforming forces acting across the fracture site.[1,2] Proper management is critical, as malunion or non-union can lead to long-term disability, pain, and compromised mobility.

Globally, distal femur fractures account for approximately 3–6% of all femoral fractures and nearly 0.4% of total fractures in adults. With the increasing age of the population and the prevalence of osteoporosis, the incidence of these fractures is expected to rise.[3] In India, road traffic accidents remain a major cause of high-energy distal femur fractures in younger patients, while osteoporotic insufficiency fractures are increasingly observed in the elderly.[4] These injuries require a delicate balance between achieving stable fixation and minimizing soft tissue damage, especially considering the functional demands of the knee joint. Historically managed with traction or cast bracing, surgical intervention is now the standard of care to enable early mobilization and prevent complications such as joint stiffness or prolonged immobilization.[5]

Currently, the two most widely accepted surgical modalities for extra-articular distal femur fractures are distal femoral locking plate fixation (LCP) and retrograde intramedullary nailing (DFN). Locking plates offer angular stability and are favored in osteoporotic bone and metaphyseal comminution.[6,7] However, they can be associated with extensive soft tissue dissection, longer operative times, and delayed union in some cases. Conversely, DFN provides a load-sharing, centrally located implant with minimal soft tissue disruption, potentially offering biomechanical advantages and faster rehabilitation.[8,9] Despite several studies comparing these techniques, the literature remains inconclusive regarding their relative superiority, particularly in functional recovery and complication resilience. Many prior studies have focused on union rates or technical parameters, with less emphasis on comprehensive outcome measures such as Neer scores, range of motion, and patient capacity to return to work. Moreover, treatment selection is often influenced by surgeon preference rather than patient- or fracture-specific criteria. In this context, our study was undertaken to provide a prospective comparison of DFN and LCP techniques using both functional and radiological parameters. We aimed to identify which fixation method offers better recovery profiles, fewer complications, and more predictable outcomes, thereby informing evidence-based clinical decision-making for extra-articular distal femur fractures.

MATERIALS AND METHODS

Study Design and Setting

This study was designed as a prospective observational investigation conducted at the Department of Orthopaedics and Trauma Centre, J.A. Group of Hospitals, Gwalior, Madhya Pradesh, India.

Study Objectives

The primary objective of this study was to assess and compare the clinical efficacy of retrograde intramedullary nailing and distal femoral locking plate fixation in the management of extra-articular distal femur fractures. Specifically, the study aimed to evaluate the two techniques in terms of functional performance, radiological healing, and patient recovery.

Secondary objectives included a comparative analysis of knee joint mobility, time to achieve full weight-bearing, and incidence of postoperative complications such as malunion, nonunion, and infection. The study also sought to determine the relative impact of each fixation method on long-term anatomical restoration and patient-reported outcomes at twelve months following surgery.

Study Participants

A total of forty adult patients diagnosed with extra-articular distal femur fractures were enrolled in the study. All participants were recruited from the inpatient and emergency services of the Department of Orthopaedics at J.A. Group of Hospitals, Gwalior. Patients were selected using simple randomization and were evenly assigned to one of two treatment groups: Group 1 underwent distal femoral locking plate fixation (n = 20), and Group 2 received retrograde intramedullary nailing (n = 20).

Eligible participants included skeletally mature adults aged 18 years or older who sustained AO/OTA type 33-A fractures of the distal femur. Both closed fractures and Gustilo-Anderson type I or II open fractures were included. Patients were required to have been independently ambulatory prior to injury and to have provided informed consent for participation.

Patients were excluded if they were below 18 years of age, had sustained fractures resulting from underlying pathological conditions, or presented with Gustilo-Anderson type III open fractures. Additional exclusion criteria included refusal to consent, or radiographic evidence of intra-articular extension of the distal femoral fracture (i.e., AO type 33-B or 33-C patterns).

Sample Size Calculation

The sample size for this study was determined based on previously published data by Charel et al. (2023), which reported a statistically significant difference in Knee Injury and Osteoarthritis Outcome Scores (KOOS) between patients treated with intramedullary nailing (mean ± SD: 86.2 ± 10.6) and those treated with plate fixation (mean ± SD: 63.8 ± 9.4). Using these parameters, a minimum of four participants per group was calculated to achieve 80% power at a 5% level of significance for a two-tailed test.

To enhance the robustness and generalizability of the findings, the sample size was deliberately expanded to include twenty participants in each group. Thus, the final study cohort consisted of forty patients, with equal allocation to the retrograde intramedullary nailing and locking plate fixation arms.

Study Procedure

Following hospital admission, all eligible patients underwent a comprehensive evaluation, including detailed documentation of demographic characteristics, mechanism of injury, relevant medical history, and associated comorbidities. Initial management adhered to the Advanced Trauma Life Support (ATLS) guidelines to ensure stabilization. After obtaining written informed consent, patients were randomly assigned to one of two treatment groups using a computer-generated random number table.

Surgical interventions were performed either electively or on an emergency basis, depending on the patient's clinical condition and operating room availability. In the locking plate fixation group, patients were positioned supine on a radiolucent operating table. Depending on the fracture morphology, either open reduction with internal fixation (utilizing the standard lateral or Swashbuckler approach) or minimally invasive percutaneous plate osteosynthesis (MIPPO) techniques were employed. Implant selection and surgical technique were standardized but left to the discretion of the attending surgeon within predefined protocol parameters.

In the retrograde intramedullary nailing group, patients were also positioned supine on a radiolucent table, with the affected knee slightly flexed. A 3-centimeter longitudinal incision was made at the lower pole of the patella, and a transpatellar tendon approach was used to access the intercondylar notch. The entry point for nail insertion was carefully identified just superior and medial to the femoral attachment of the posterior cruciate ligament. After guidewire placement and medullary canal reaming, an appropriately sized intramedullary nail was inserted. Fixation was achieved with at least two distal locking screws, and the proximal end of the nail was seated approximately 3 mm below the articular surface of the distal femur, ensuring secure stabilization under fluoroscopic guidance.

All patients received standard postoperative care, including antibiotic prophylaxis, thromboprophylaxis, and physiotherapy tailored to fixation stability and pain tolerance. Follow-up assessments were conducted at regular intervals, with final evaluation at 12 months postoperatively.

Outcome Measures

Clinical, functional, and radiological outcomes were assessed at standardized follow-up intervals, culminating in a comprehensive evaluation at 12 months postoperatively. Functional outcomes were measured using the Neer scoring system, which incorporates assessments of pain, function, range of motion, and return to work. Knee flexion was recorded in degrees using a goniometer, and pain levels were evaluated using a standardized pain subscore embedded within the Neer criteria.

Radiological outcomes were assessed using plain anteroposterior and lateral radiographs of the distal femur. Healing was evaluated based on cortical bridging and alignment, with scoring derived from established roentgenographic criteria. Time to full weight-bearing was documented in weeks from the date of surgery, guided by clinical judgment and radiological evidence of union. Postoperative complications, including malunion, nonunion, and infection, were also recorded and analyzed.

All outcome assessments were conducted by clinicians blinded to the intervention group to minimize observer bias.

Statistical Analysis

All data were analyzed using the Statistical Package for the Social Sciences (SPSS), version 20.0 (IBM Corp., Armonk, NY, USA). Descriptive statistics were computed for demographic variables and outcome measures. Continuous variables were expressed as means and standard deviations, while categorical data were presented as frequencies and percentages.

Comparative analysis between the two intervention groups was performed using the unpaired Student's t-test for continuous variables and the chi-square test for categorical variables. A p-value of less than 0.05 was considered statistically significant, and values below 0.01 were regarded as highly significant. All statistical tests were two-tailed.

Ethical Consideration

The study protocol was reviewed and approved by the Institutional Ethics Committee of G.R. Medical College and J.A. Group of Hospitals, Gwalior, prior to the initiation of patient enrollment. All participants provided written informed consent after receiving a detailed explanation of the study objectives, procedures, potential risks, and benefits. Confidentiality of patient data was strictly maintained throughout the study, and all procedures adhered to the ethical principles outlined in the Declaration of Helsinki and its subsequent amendments.

RESULTS

1. Demographic and Clinical Baseline Characteristics

The demographic distribution of patients across the two treatment groups was comparable. The retrograde intramedullary nailing (DFN) group included 17 males (85%) and 3 females (15%), while the locking plate (LCP) group comprised 14 males (70%) and 6 females (30%). Although a higher proportion of females were observed in the LCP group, this difference was not statistically significant and likely reflects the trauma exposure profile rather than treatment allocation.

Laterality of the injury was evenly distributed between groups, with the right femur affected in 45% of DFN cases and 55% of LCP cases. Left-sided involvement was observed in 55% of DFN cases and 45% of LCP cases, indicating no predilection for laterality across fixation methods.

The mean duration between injury and surgical intervention was similar between groups. Patients in

the DFN group underwent surgery after a mean of 2.1 ± 1.4 days, while those in the LCP group were treated after 2.2 ± 1.6 days (p = 0.836), suggesting uniform urgency in operative management.

Table 1: Baseline Demographic and Clinical Characteristics

Parameter	DFN (n = 20)	LCP (n = 20)	p-value
Gender			
Male	17 (85%)	14 (70%)	—
Female	3 (15%)	6 (30%)	
Side Involved			
Right	9 (45%)	11 (55%)	—
Left	11 (55%)	9 (45%)	
Time from Injury to Surgery			
Mean ± SD (days)	2.1 ± 1.4	2.2 ± 1.6	0.836
Range (days)	1 – 6	1 – 6	

2. Operative Parameters and Time to Weight-Bearing

The mean duration of surgery was significantly shorter in the DFN group compared to the LCP group. Patients undergoing retrograde intramedullary nailing had a mean operative time of 76.1 ± 7.8 minutes, whereas those treated with locking plate fixation required an average of 105.4 ± 9.9 minutes (p < 0.001). This reflects a clear time-efficiency advantage associated with the intramedullary approach.

A notable difference was also observed in postoperative rehabilitation timelines. The DFN group achieved full weight-bearing at an average of 16.6 ± 3.6 weeks, significantly earlier than the LCP group, which required 26.1 ± 3.8 weeks (p < 0.001). The nearly 10-week differential underscores the biomechanical advantage and early mobilization benefits of intramedullary fixation.

Table 2: Operative Parameters and Weight-Bearing Time

Parameter	DFN (n = 20)	LCP (n = 20)	p-value
Duration of Surgery (minutes)			<0.001*
Mean ± SD	76.1 ± 7.8	105.4 ± 9.9	
Range	63 – 92	90 – 122	
Time to Full Weight-Bearing (weeks)			<0.001*
Mean ± SD	16.6 ± 3.6	26.1 ± 3.8	
Range	12 – 24	20 – 32	

3. Functional Outcomes at 12 Months

Functional assessment at one year revealed that both fixation techniques yielded satisfactory overall recovery, but the DFN group consistently demonstrated superior outcomes in specific domains. Pain scores were similar between groups, with no statistically significant difference (DFN: 11.8 ± 4.0; LCP: 12.2 ± 3.8; p = 0.748). However, a marked advantage was observed in **knee flexion**, where DFN patients achieved significantly greater mobility (17.6 ± 2.4 vs 12.6 ± 4.0; p < 0.001). Notably, 95% of DFN patients attained "excellent" flexion (≥16), compared to only 40% in the LCP group.

Work scores also favored the DFN group, with all patients achieving the maximum score of 10, whereas the LCP group showed variable recovery (mean: 8.7 ± 2.2; p = 0.013). Similarly, the **total functional score**, which aggregates pain, function, work, and motion subscores, was significantly higher in the DFN group (54.6 ± 8.6 vs 48.7 ± 10.9; p = 0.024). Function subscores alone (based on daily activities) were nearly identical across groups (mean: 15.2), suggesting that differences were more apparent in physical recovery metrics rather than self-reported general function.

Table 3: Functional Outcomes at 12 Months

Parameter	DFN (n = 20)	LCP (n = 20)	p-value
Pain Score			0.748
Mean ± SD	11.8 ± 4.0	12.2 ± 3.8	
Function Score			1.000
Mean ± SD	15.2 ± 3.3	15.2 ± 3.1	
Knee Flexion Score			<0.001*
Mean ± SD	17.6 ± 2.4	12.6 ± 4.0	
Work Score			0.013*
Mean ± SD	10.0 ± 0.0	8.7 ± 2.2	
Total Functional Score			0.024*
Mean ± SD	54.6 ± 8.6	48.7 ± 10.9	

4. Radiological and Anatomical Outcomes

Radiographic evaluation at 12 months postoperatively revealed significantly better anatomical restoration and alignment in patients treated with retrograde intramedullary nailing. The DFN group achieved a higher **gross anatomical score** (mean: 14.7 ± 1.3) compared to the LCP group

(mean: 13.7 ± 2.3; p = 0.034), indicating more consistent restoration of mechanical alignment.

Similarly, **roentgenographic scores**, which reflect cortical bridging and maintenance of reduction, were superior in the DFN group (13.8 ± 2.3 vs 11.4 ± 3.8; p = 0.021), suggesting more robust and earlier radiological consolidation.

The **total anatomical score**, incorporating both gross alignment and radiographic healing, was significantly higher in the DFN group (28.5 ± 3.4 vs 25.1 ± 5.7; p = 0.027). Moreover, 70% of DFN patients achieved an "excellent" anatomical score (score = 30), compared to only 35% in the LCP group (p = 0.019).

These findings support the notion that intramedullary fixation promotes superior anatomical alignment and radiological healing, even in the presence of technical or biological challenges.

Table 4: Radiological and Anatomical Outcomes at 12 Months

Parameter	DFN (n = 20)	LCP (n = 20)	p-value
Gross Anatomical Score	14.7 ± 1.3	13.7 ± 2.3	0.034*
Roentgenogram Score	13.8 ± 2.3	11.4 ± 3.8	0.021*
Total Anatomical Score	28.5 ± 3.4	25.1 ± 5.7	0.027*
% Excellent (Score = 30)	70% (14/20)	35% (7/20)	0.019*

5. Neer Functional Scores at 12 Months

The Neer scoring system, a composite measure of pain, function, range of motion, and return to activity, demonstrated significantly better overall outcomes in the retrograde nailing (DFN) group compared to the locking plate (LCP) group at one-year follow-up. The mean Neer score was **83.1 ± 11.3** in the DFN group versus **73.7 ± 16.2** in the LCP group, representing a statistically significant difference (p = 0.012).

Importantly, **55%** of DFN patients achieved "excellent" outcomes (score >85), compared to only **25%** in the LCP group (p = 0.008). Conversely, poor outcomes (score <55) were more frequent in the LCP group (20%) than in the DFN group (5%). These results underscore the superior composite recovery profile associated with intramedullary fixation, not only in terms of pain and motion but also in functional reintegration and activity tolerance.

Table 5: Neer Functional Scores at 12 Months

Parameter	DFN (n = 20)	LCP (n = 20)	p-value
Mean Neer Score ± SD	83.1 ± 11.3	73.7 ± 16.2	0.012*
Score Distribution			
Excellent (>85)	11 (55%)	5 (25%)	0.008*
Good (70–85)	8 (40%)	10 (50%)	—
Fair (55–69)	0 (0%)	1 (5%)	—
Poor (<55)	1 (5%)	4 (20%)	—

6. Postoperative Complications and Final Outcomes

The overall complication rates were similar between the two treatment groups, with complications observed in **35%** of patients treated with distal femoral nailing (DFN) and **40%** of those treated with locking compression plating (LCP) (p = 0.744). Malunion occurred more frequently in the DFN group (30% vs 20%), while non-union was notably more prevalent in the LCP group (20% vs 5%), although these differences did not reach statistical significance. Infection rates were comparable across both cohorts.

Despite similar complication rates, **final functional outcomes diverged significantly**. At 12 months, **55%** of DFN patients achieved "excellent" results compared to only **25%** in the LCP group (p = 0.048).

Poor outcomes were observed in 5% of DFN cases and 20% of LCP cases. This indicates that DFN fixation not only yielded better overall results but also demonstrated greater resilience in the face of complications.

Stratified analysis further reinforced this pattern. Among patients **without complications**, 84.6% of DFN recipients achieved excellent outcomes versus 41.7% in the LCP group (p = 0.027). Even among those **with complications**, the DFN group maintained superior results, with 85.7% achieving at least a satisfactory outcome compared to just 37.5% in the LCP group (p = 0.043). These findings suggest that retrograde nailing provides more consistent and robust functional recovery, even when adverse events occur.

Table 6: Postoperative Complications and Final Outcomes

Parameter	DFN (n = 20)	LCP (n = 20)	p-value
Complications			
Malunion	6 (30.0%)	4 (20.0%)	0.465
Non-union	1 (5.0%)	4 (20.0%)	0.151
Infection	2 (10.0%)	3 (15.0%)	0.633
Any Complication	7 (35.0%)	8 (40.0%)	0.744
Final Outcome – All Cases			
Excellent	11 (55.0%)	5 (25.0%)	0.048*
Satisfactory	8 (40.0%)	10 (50.0%)	0.525
Unsatisfactory	0 (0%)	1 (5.0%)	0.311

Poor (Failure)	1 (5.0%)	4 (20.0%)	0.151
Outcomes in Patients without Complications			
Excellent	11/13 (84.6%)	5/12 (41.7%)	0.027*
Satisfactory	2/13 (15.4%)	7/12 (58.3%)	0.035*
Outcomes in Patients with Complications			
Satisfactory	6/7 (85.7%)	3/8 (37.5%)	0.043*
Poor	1/7 (14.3%)	4/8 (50.0%)	0.157

DISCUSSION

The present study was designed to compare the clinical, functional, and radiological outcomes of retrograde intramedullary nailing (DFN) versus locking compression plating (LCP) in the management of extra-articular distal femur fractures. This investigation was motivated by ongoing debate regarding optimal fixation strategies for such injuries, particularly in the context of early mobilization, soft tissue preservation, and complication risk. Our results revealed clear advantages of DFN in terms of overall function, anatomical alignment, and rehabilitation timeline, providing evidence in favor of its biomechanical and biological superiority.

With respect to primary outcomes, patients treated with retrograde nailing demonstrated significantly higher Neer functional scores and total anatomical scores than those treated with plate fixation. These findings are supported by the work of Rysselberghe et al. (2023), who found that intramedullary fixation preserved quadriceps strength and improved postoperative mobility due to its minimally invasive nature.[10] The reduced disruption of periarticular tissues in DFN may enhance early mobilization and muscle recovery, translating to improved composite scores. In addition, Gengatharan et al. (2024) highlighted the role of osteo-inductive signaling and optimized calcium-phosphorus balance in promoting healing, both of which may be better supported by the stable, load-sharing environment offered by intramedullary devices.[11] These mechanobiological factors likely contribute to the enhanced functional and radiographic recovery observed in the DFN cohort.

The secondary outcomes of the study—particularly knee flexion and time to full weight-bearing—also favored the DFN group. Our data showed that DFN patients achieved earlier rehabilitation milestones and superior knee range of motion at one year. These findings align with Rysselberghe et al., who demonstrated that intramedullary nails lead to less quadriceps atrophy and better preservation of knee function.[10] The rigid internal stabilization provided by DFN enables earlier physiotherapy initiation, a critical determinant of joint mobility. While both groups exhibited comparable pain relief, the functional recovery was faster and more consistent with DFN, suggesting a biomechanical advantage that goes beyond symptomatic control. Moreover, complication analysis revealed lower non-union rates in the DFN group—consistent with the observations of Yang et al. (2022) and Ziranu et al. (2022), who identified inadequate implant stability as a key contributor to hardware failure and revision.[12,13]

Overall, the superior outcomes associated with DFN can be attributed to several interrelated mechanisms: its central alignment along the mechanical axis, load-sharing biomechanics, minimally invasive technique, and enhanced biological healing environment. These factors likely synergize to preserve periosteal blood flow, reduce soft tissue trauma, and accelerate osteogenesis—elements emphasized by both Gengatharan et al. and Yang et al. in their discussions of successful fracture healing. Our findings support a treatment algorithm that favors DFN in eligible patients, particularly when early mobilization and muscle function recovery are clinical priorities.[11,12]

Nonetheless, certain limitations must be acknowledged. The modest sample size and single-center design may limit generalizability. Additionally, while functional and radiological parameters were comprehensively evaluated, long-term follow-up beyond one year was not performed, and patient-reported quality-of-life metrics were not assessed.

CONCLUSION

Retrograde intramedullary nailing demonstrated superior functional, radiological, and rehabilitative outcomes compared to locking plate fixation in the management of extra-articular distal femur fractures. Its minimally invasive approach, enhanced mechanical stability, and earlier mobilization contribute to improved recovery. Given its consistent performance even in the presence of complications, DFN should be considered the preferred fixation method when patient and fracture characteristics are appropriate.

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