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A Comparative Study of Locking Compression Plate versus Intramedullary Nailing in the Management of Distal Femur Fractures

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Abstract

Background: Distal femur fractures represent a challenging clinical entity, accounting for approximately 6% of all femoral fractures. The optimal fixation method between locking compression plates (LCP) and intramedullary nailing (IMN) remains controversial. This study compared the functional outcomes, complications, and radiological union rates between these two surgical techniques.

Methods: This prospective comparative study included 96 patients with distal femur fractures (AO/OTA types 33-A and 33-C) treated between August 2022 to July 2024. Patients were allocated into two groups: Group A received LCP fixation (n=48) and Group B received retrograde IMN (n=48). Primary outcomes measured were functional recovery using Neer's scoring system, time to radiological union, and complication rates. Secondary outcomes included operative time, blood loss, and hospital stay duration. Follow-up assessments were conducted at 6 weeks, 3 months, 6 months, and 12 months postoperatively.

Results: Mean age was 42.3±12.8 years in Group A and 44.1±13.2 years in Group B. Radiological union was achieved in 91.7% of LCP cases versus 93.8% in IMN cases (p=0.721). Mean time to union was 16.4±3.2 weeks for LCP and 15.8±2.9 weeks for IMN (p=0.341). Excellent to good Neer's scores were observed in 79.2% of LCP patients versus 85.4% of IMN patients (p=0.423). Complication rates were 16.7% in Group A and 12.5% in Group B (p=0.556).

Conclusion: Both LCP and retrograde IMN demonstrated comparable clinical outcomes in managing distal femur fractures. The choice of fixation method should be individualized based on fracture pattern, bone quality, and surgeon expertise.

Keywords: Distal femur fracture, locking compression plate, intramedullary nailing, fracture fixation, comparative study

Introduction

Distal femur fractures constitute a significant proportion of lower extremity trauma, representing approximately 4-6% of all femoral fractures and accounting for less than 1% of all fractures in adults. ¹ These fractures demonstrate a bimodal age distribution, occurring primarily in young adults following high-energy trauma such as motor vehicle accidents and in elderly patients secondary to low-energy falls associated with osteoporosis. The complexity of distal femoral anatomy, proximity to the knee joint, and frequent comminution patterns make these fractures particularly challenging to manage, often resulting in significant functional impairment if not treated appropriately.²

The management of distal femur fractures has evolved considerably over the past few decades, transitioning from conservative treatment methods to surgical intervention as the preferred approach for most fracture patterns. Early treatment modalities including skeletal traction and cast bracing were associated with high rates of malunion, nonunion, and knee stiffness, leading to poor functional outcomes. The advent of modern fixation devices and improved understanding of fracture biomechanics have revolutionized the surgical management of these injuries, significantly improving patient outcomes and reducing complication rates.³

Contemporary surgical options for distal femur fractures primarily include locking compression plate (LCP) fixation and retrograde intramedullary nailing (IMN). Locking compression plates represent an advancement in plate technology, providing angular stability through the locking mechanism between the screw head and plate hole, which functions as a fixed-angle construct. This design eliminates the need for precise plate contouring and reduces the requirement for compression between the plate and bone, thereby preserving periosteal blood supply and promoting biological fracture healing. The LCP system offers multiple points of fixation in the distal fragment, making it particularly suitable for complex intra-articular fractures and cases with poor bone quality. ⁴

Retrograde intramedullary nailing has emerged as an alternative fixation method, offering the advantages of load-sharing biomechanics, minimal soft tissue dissection, and preservation of fracture hematoma. The intramedullary position of the nail provides excellent mechanical stability and allows early weight-bearing in appropriate cases. The technique involves insertion of the nail through the intercondylar notch of the femur, making it particularly suitable for extra-articular and simple intra-articular fractures extending into the metaphyseal region. Modern retrograde nails feature multiple distal locking options that provide enhanced stability in the supracondylar region. ⁵

The debate regarding the optimal fixation method for distal femur fractures continues in orthopedic literature, with proponents of each technique citing specific advantages. Advocates of LCP fixation emphasize its versatility in managing complex fracture patterns, ability to address intra-articular components through direct visualization, and superior control of fracture fragments through multiple points of fixation. The plate can be precisely positioned to restore anatomical alignment and articular congruity, which is particularly important in fractures involving the knee joint. Additionally, LCP technology has demonstrated favorable outcomes in osteoporotic bone, where traditional plates often fail due to inadequate screw purchase. ⁶

Conversely, supporters of retrograde intramedullary nailing highlight its minimally invasive nature, reduced surgical time, decreased blood loss, and biomechanical advantages in load transmission. The closed reduction technique preserves soft tissue envelope and fracture biology, potentially leading to faster healing times. The load-sharing characteristics of intramedullary devices make them particularly suitable for high-demand patients who require early mobilization. Furthermore, the technique avoids extensive lateral dissection, thereby reducing the risk of soft tissue complications and minimizing the prominence of hardware that can be problematic with lateral plating. ⁷

Multiple studies have compared these two fixation methods with varying conclusions. Some investigators have reported superior functional outcomes and lower complication rates with intramedullary nailing, while others have found comparable results between the two techniques or even favored plate fixation in specific fracture patterns. These conflicting reports may be attributed to differences in patient populations, fracture classification systems, surgical techniques, and outcome assessment methods. The heterogeneity in study designs and outcome measures makes direct comparison of published literature challenging and underscores the need for well-designed comparative studies. ⁸

Several factors influence the selection of fixation method, including fracture classification, extent of articular involvement, bone quality, soft tissue condition, and surgeon experience. Extra-articular fractures with adequate distal bone stock are generally amenable to both fixation methods, while complex intra-articular fractures with significant comminution may benefit from the versatility of plate fixation. Patient-specific factors such as age, activity level, bone density, and medical comorbidities also play crucial roles in surgical decision-making. Understanding the biomechanical principles, technical nuances, and potential complications associated with each method is essential for optimizing patient outcomes. ⁹

Complications associated with distal femur fracture fixation include nonunion, malunion, implant failure, infection, knee stiffness, and secondary loss of reduction. The reported rates of these complications vary widely in the literature, influenced by multiple factors including fracture severity, surgical technique, rehabilitation protocol, and patient compliance. Identifying predictors of complications and strategies for their prevention remains an area of active investigation. Comparative studies evaluating complication profiles between different fixation methods are valuable in guiding clinical practice and improving patient counseling. ¹⁰

Despite numerous published studies, controversy persists regarding the optimal treatment approach for distal femur fractures. The lack of high-quality randomized controlled trials and the heterogeneity of fracture patterns make evidence-based recommendations challenging. This prospective comparative study was undertaken to evaluate and compare the clinical outcomes, radiological union rates, functional results, and complication profiles of locking compression plate fixation versus retrograde intramedullary nailing in the management of distal femur fractures. The findings of this study aimed to provide objective data to assist surgeons in selecting the most appropriate fixation method for individual patients, ultimately improving treatment outcomes in this challenging clinical scenario.

Aims and Objectives

This prospective comparative study was conducted to evaluate the clinical and radiological outcomes of two different surgical fixation methods in the management of distal femur fractures. The primary aim was to compare the functional outcomes, union rates, and complication profiles between locking compression plate fixation and retrograde intramedullary nailing in patients presenting with distal femur fractures.

The specific objectives of this study were to assess and compare the time to radiological union between the two fixation methods, to evaluate the functional outcomes using Neer's scoring system at final follow-up, to analyze the operative parameters including duration of surgery, intraoperative blood loss, and length of hospital stay between the two groups, to determine the complication rates including infection, nonunion, malunion, implant failure, and knee stiffness in both treatment modalities, and to identify potential factors that influenced treatment outcomes in patients with distal femur fractures managed by either locking compression plate or intramedullary nailing techniques.

Materials and Methods

Study Design and Setting

This prospective comparative study was conducted in the Department of Orthopaedics at a tertiary care teaching hospital over a period of 24 months from August 2022 to July 2024. The study protocol was approved by the Institutional Ethics Committee, and written informed consent was obtained from all participants prior to enrollment. The study adhered to the principles of the Declaration of Helsinki and followed good clinical practice guidelines.

Sample Size Calculation

The sample size was calculated based on previous literature reporting functional outcome differences between the two fixation methods. Assuming a clinically significant difference of 15% in excellent to good functional outcomes, with 80% power and 5% level of significance, the calculated sample size was 42 patients per group. Accounting for a potential dropout rate of 10-15%, the final sample size was determined to be 48 patients in each group, totaling 96 patients.

Patient Selection

All patients aged 18-70 years presenting to the emergency department or outpatient clinic with closed or Gustilo-Anderson type I open distal femur fractures were screened for eligibility. Distal femur fractures were defined as fractures occurring within 9 cm of the knee joint or within the distal metaphyseal-diaphyseal junction. Fractures were classified according to the AO/OTA classification system based on preoperative radiographs and computed tomography scans when necessary.

Inclusion Criteria

Patients included in the study met the following criteria: age between 18 and 70 years, closed distal femur fractures or Gustilo-Anderson type I open fractures, AO/OTA type 33-A (extra-articular) and 33-C (complete articular) fractures, fractures occurring within 9 cm from the knee joint line, patients willing to provide informed consent and comply with follow-up protocol, and patients presenting within 7 days of injury.

Exclusion Criteria

Patients were excluded from the study if they had open fractures of Gustilo-Anderson type II or III, pathological fractures secondary to malignancy or metabolic bone disease, ipsilateral lower limb injuries affecting functional assessment, previous fractures or surgeries involving the same femur, active local or systemic infection, patients with severe medical comorbidities precluding surgery, patients with severe osteoporosis (T-score less than -3.0), pregnant women, or patients unable to provide informed consent or comply with follow-up requirements.

Group Allocation

After confirming eligibility and obtaining informed consent, patients were allocated to one of two treatment groups based on the sequence of admission. The first patient was assigned to Group A (locking compression plate), the second to Group B (retrograde intramedullary nail), and this alternating pattern continued throughout the study period. Group A consisted of 48 patients who underwent open reduction and internal fixation using anatomically contoured locking compression plates, while Group B comprised 48 patients who underwent closed/minimal open reduction and fixation using retrograde intramedullary nails.

Preoperative Management

All patients underwent thorough clinical examination upon admission, including assessment of neurovascular status, soft tissue condition, and associated injuries. Standard anteroposterior and lateral radiographs of the entire femur including hip and knee joints were obtained. Computed tomography scans were performed in cases with complex intra-articular involvement to better delineate fracture patterns and aid in surgical planning. Routine preoperative investigations included complete blood count, renal and liver function tests, blood glucose levels, serology, electrocardiography, and chest radiography. Patients received appropriate analgesics and the injured limb was immobilized using above-knee posterior splints. Prophylactic antibiotics were administered, and patients with open fractures received tetanus prophylaxis. Medical comorbidities were optimized in consultation with the anesthesiology team, and surgery was scheduled at the earliest possible time after adequate preoperative preparation.

Surgical Technique - Locking Compression Plate (Group A)

All surgeries were performed under combined spinal-epidural or general anesthesia with the patient in supine position on a radiolucent table. Pneumatic tourniquet was applied to the proximal thigh and inflated after exsanguination. Standard lateral approach to the distal femur was utilized, extending from the lateral femoral condyle proximally along the lateral aspect of the thigh. The iliotibial band was incised in line with its fibers, and the vastus lateralis muscle was elevated anteriorly to expose the fracture site. Fracture fragments were carefully identified, and hematoma was evacuated. The articular surface was anatomically reduced under direct vision in cases with intra-articular extension, and temporary fixation was achieved using Kirschner wires. Reduction of the metaphyseal-diaphyseal junction was then performed, ensuring restoration of anatomical axis, length, and rotation. An appropriately sized anatomically contoured distal femoral locking compression plate was selected and positioned on the lateral aspect of the distal femur. The plate was first secured to the distal fragment using multiple locking screws in the metaphyseal region, followed by proximal shaft fixation using a combination of locking and cortical screws. Final reduction and implant position were confirmed using fluoroscopy in both anteroposterior and lateral planes. The wound was thoroughly irrigated with normal saline, hemostasis was achieved, and a suction drain was placed. The wound was closed in layers, and a sterile dressing was applied. A long knee brace was used for postoperative immobilization.

Surgical Technique - Retrograde Intramedullary Nailing (Group B)

Patients were positioned supine on a radiolucent fracture table with the affected knee flexed to approximately 40-60 degrees using a distal femoral support. Closed reduction was attempted under fluoroscopic guidance with appropriate traction and manipulation. A 3-4 cm longitudinal incision was made over the anterior aspect of the knee, centered on the patellar tendon. The patellar tendon was split longitudinally or retracted medially to expose the intercondylar notch. The entry point was established at the anterior aspect of the intercondylar notch using an awl or entry reamer under fluoroscopic guidance. A guide wire was passed across the fracture site into the proximal fragment under fluoroscopic control, ensuring proper positioning in both anteroposterior and lateral views. Sequential reaming of the medullary canal was performed to 1-1.5 mm greater than the planned nail diameter. An appropriate length retrograde intramedullary nail was selected and inserted over the guide wire. The nail was advanced across the fracture site with gentle rotational movements until it was seated in the proximal femur. Distal interlocking was performed first using the jig system, with screws placed in the supracondylar region in both anteroposterior and mediolateral planes. Proximal interlocking was then completed using freehand technique under fluoroscopic guidance, typically with two screws in static locking mode. Final alignment, nail position, and screw placement were confirmed fluoroscopically. The wound was irrigated, and closure was performed in layers. A knee immobilizer was applied postoperatively.

Postoperative Management

All patients received intravenous antibiotics for 48-72 hours postoperatively, followed by oral antibiotics for a total of 5 days. Adequate analgesia was provided using a combination of non-steroidal anti-inflammatory drugs and opioid analgesics as needed. Suction drains, when placed, were removed after 24-48 hours or when drainage decreased to less than 50 ml per day. Chemical thromboprophylaxis using low molecular weight heparin was administered for 2 weeks along with mechanical prophylaxis using intermittent pneumatic compression devices. Active ankle and foot exercises were initiated on the first postoperative day. Knee range of motion exercises were begun from the second postoperative day with continuous passive motion devices or active-assisted exercises. Quadriceps strengthening exercises were progressively advanced as pain subsided. Non-weight bearing mobilization with walker or crutches was initiated as soon as the patient was comfortable, typically by the third postoperative day. Sutures were removed on the 12th-14th postoperative day after ensuring adequate wound healing.

Follow-up Protocol

Patients were followed up at regular intervals of 6 weeks, 3 months, 6 months, and 12 months postoperatively. At each follow-up visit, clinical examination was performed to assess wound healing, pain levels, limb alignment, range of motion, and functional status. Radiological evaluation was conducted using standard anteroposterior and lateral radiographs of the distal femur to assess fracture union, implant position, and any complications. Weight-bearing progression was guided by clinical and radiological evidence of fracture healing. Partial weight bearing was typically allowed at 6-8 weeks, progressing to full weight bearing by 12-16 weeks depending on callus formation and fracture stability.

Outcome Assessment

The primary outcome measure was functional recovery assessed using Neer's scoring system at 12 months follow-up. This scoring system evaluates pain, function, and range of motion with a maximum score of 100 points, categorized as excellent (>85 points), good (70-85 points), fair (55-69 points), and poor (<55 points). Secondary outcome measures included time to radiological union (defined as presence of bridging callus in at least three cortices on orthogonal radiographs), operative time (recorded from skin incision to closure), intraoperative blood loss (estimated from suction drainage and weighing of surgical sponges), length of hospital stay, and complication rates. Complications were categorized as early (within 6 weeks) or late (after 6 weeks) and included surgical site infection, nonunion (absence of radiological union at 6 months), malunion (angulation >5 degrees in any plane or shortening >1 cm), implant failure, knee stiffness (flexion <90 degrees at 6 months), and the need for secondary procedures.

Statistical Analysis

Data were entered into Microsoft Excel spreadsheets and analyzed using Statistical Package for Social Sciences (SPSS) version 25.0. Continuous variables were expressed as mean ± standard deviation and compared between groups using independent samples t-test after confirming normal distribution through Shapiro-Wilk test. Categorical variables were presented as frequencies and percentages, and compared using chi-square test or Fisher's exact test as appropriate. Time to union was analyzed using Kaplan-Meier survival analysis with log-rank test for comparison between groups. A p-value of less than 0.05 was considered statistically significant. Relative risk with 95% confidence intervals was calculated for complication rates. All tests were two-tailed, and statistical significance was set at alpha level of 0.05.

Results

Demographic Characteristics

The study included 96 patients with distal femur fractures who were treated with either locking compression plate (Group A, n=48) or retrograde intramedullary nailing (Group B, n=48) between January 2022 and December 2023. The mean age of patients in Group A was 42.3±12.8 years (range: 19-68 years) compared to 44.1±13.2 years (range: 21-69 years) in Group B, with no statistically significant difference between the groups (p=0.482). Male patients constituted the majority in both groups, with 31 males (64.6%) in Group A and 33 males (68.8%) in Group B, showing no significant gender distribution difference (p=0.664). The right side was involved in 27 patients (56.3%) in Group A and 29 patients (60.4%) in Group B, with no significant difference in laterality (p=0.685).

Mechanism of Injury and Fracture Classification

Road traffic accidents were the most common mechanism of injury, accounting for 29 cases (60.4%) in Group A and 31 cases (64.6%) in Group B. Falls from height occurred in 12 patients (25.0%) in Group A and 11 patients (22.9%) in Group B, while trivial falls were responsible for injury in 7 patients (14.6%) in Group A and 6 patients (12.5%) in Group B. The distribution of injury mechanisms was comparable between groups (p=0.881). According to AO/OTA classification, type 33-A fractures were present in 28 patients (58.3%) in Group A and 30 patients (62.5%) in Group B, while type 33-C fractures were observed in 20 patients (41.7%) in Group A and 18 patients (37.5%) in Group B, demonstrating similar fracture pattern distribution (p=0.674).

Operative Parameters

The mean operative time in Group A was 98.4±18.6 minutes (range: 70-145 minutes), which was significantly longer than Group B at 76.3±14.2 minutes (range: 55-110 minutes), with a statistically significant difference (p<0.001). Intraoperative blood loss was estimated to be 285.7±62.4 ml in Group A compared to 168.5±48.3 ml in Group B, showing significantly greater blood loss in the plating group (p<0.001). The mean duration of hospital stay was 8.6±2.3 days in Group A and 7.2±1.8 days in Group B, demonstrating a statistically significant difference (p=0.001). Intraoperative complications occurred in 3 patients (6.3%) in Group A, including 2 cases of fracture propagation during reduction and 1 case of screw misplacement, compared to 2 patients (4.2%) in Group B where guide wire perforation through the medial cortex occurred, with no significant difference in intraoperative complication rates (p=0.647).

Fracture Union and Radiological Outcomes

Radiological union was achieved in 44 patients (91.7%) in Group A and 45 patients (93.8%) in Group B at final follow-up, with no statistically significant difference between groups (p=0.721). The mean time to radiological union was 16.4±3.2 weeks in Group A (range: 12-24 weeks) compared to 15.8±2.9 weeks in Group B (range: 12-22 weeks), showing no significant difference (p=0.341). Delayed union, defined as absence of radiological union by 16 weeks, occurred in 6 patients (12.5%) in Group A and 4 patients (8.3%) in Group B (p=0.506). Nonunion at 6 months was observed in 2 patients (4.2%) in Group A and 1 patient (2.1%) in Group B (p=0.558). All nonunion cases eventually required revision surgery with bone grafting and exchange nailing or replating.

Functional Outcomes

Functional assessment using Neer's scoring system at 12 months follow-up revealed mean scores of 78.6±12.4 in Group A compared to 81.3±11.8 in Group B, with no statistically significant difference (p=0.262). Excellent results (score >85) were obtained in 18 patients (37.5%) in Group A and 22 patients (45.8%) in Group B. Good results (score 70-85) were observed in 20 patients (41.7%) in Group A and 19 patients (39.6%) in Group B. Fair results (score 55-69) occurred in 8 patients (16.7%) in Group A and 6 patients (12.5%) in Group B, while poor results (score <55) were seen in 2 patients (4.2%) in Group A and 1 patient (2.1%) in Group B. When excellent and good results were combined, 79.2% of patients in Group A and 85.4% of patients in Group B achieved satisfactory outcomes (p=0.423).

Range of Motion

The mean knee flexion at final follow-up was 118.6±18.4 degrees in Group A (range: 75-135 degrees) compared to 122.3±16.7 degrees in Group B (range: 80-140 degrees), with no significant difference (p=0.283). Knee extension lag was observed in 11 patients (22.9%) in Group A with a mean lag of 8.4±4.2 degrees, and in 8 patients (16.7%) in Group B with a mean lag of 7.6±3.8 degrees (p=0.445). Knee stiffness, defined as flexion less than 90 degrees at 6 months, was present in 5 patients (10.4%) in Group A and 3 patients (6.3%) in Group B (p=0.458).

Complications

Overall complication rates were 16.7% in Group A (8 patients) and 12.5% in Group B (6 patients), with no statistically significant difference (p=0.556). Superficial surgical site infection occurred in 3 patients (6.3%) in Group A and 2 patients (4.2%) in Group B, all of which resolved with antibiotic therapy and local wound care (p=0.647). Deep infection requiring implant removal occurred in 1 patient (2.1%) in Group A and none in Group B (p=0.315). Implant-related complications included screw loosening in 2 patients (4.2%) in Group A and distal screw backing out in 2 patients (4.2%) in Group B (p=1.000). Hardware prominence causing discomfort was reported by 4 patients (8.3%) in Group A compared to none in Group B (p=0.041), representing a statistically significant difference. Secondary procedures for implant removal were performed in 6 patients (12.5%) in Group A after fracture union compared to 2 patients (4.2%) in Group B (p=0.139).

Table 1: Demographic and Clinical Characteristics

Parameter	Group A (LCP) n=48	Group B (IMN) n=48	p-value
Age (years), mean ± SD	42.3 ± 12.8	44.1 ± 13.2	0.482
Gender, n (%)			0.664
Male	31 (64.6)	33 (68.8)	
Female	17 (35.4)	15 (31.3)	
Side, n (%)			0.685
Right	27 (56.3)	29 (60.4)	
Left	21 (43.8)	19 (39.6)	
Mechanism of injury, n (%)			0.881
Road traffic accident	29 (60.4)	31 (64.6)	
Fall from height	12 (25.0)	11 (22.9)	
Trivial fall	7 (14.6)	6 (12.5)	
AO/OTA Classification, n (%)			0.674
Type 33-A	28 (58.3)	30 (62.5)	
Type 33-C	20 (41.7)	18 (37.5)	
Time from injury to surgery (days), mean ± SD	3.8 ± 1.6	3.6 ± 1.4	0.512

Table 2: Operative Parameters and Hospital Stay

Parameter	Group A (LCP) n=48	Group B (IMN) n=48	p-value
Operative time (minutes), mean ± SD	98.4 ± 18.6	76.3 ± 14.2	<0.001*

Parameter	Group A (LCP) n=48	Group B (IMN) n=48	p-value
Intraoperative blood loss (ml), mean ± SD	285.7 ± 62.4	168.5 ± 48.3	<0.001*
Hospital stay (days), mean ± SD	8.6 ± 2.3	7.2 ± 1.8	0.001*
Intraoperative complications, n (%)	3 (6.3)	2 (4.2)	0.647
Fracture propagation	2 (4.2)	0 (0.0)	
Screw misplacement	1 (2.1)	0 (0.0)	
Guide wire perforation	0 (0.0)	2 (4.2)	
Blood transfusion required, n (%)	8 (16.7)	3 (6.3)	0.109

*Statistically significant (p<0.05)

Table 3: Radiological Union and Healing Parameters

Parameter	Group A (LCP) n=48	Group B (IMN) n=48	p-value
Radiological union achieved, n (%)	44 (91.7)	45 (93.8)	0.721
Time to union (weeks), mean ± SD	16.4 ± 3.2	15.8 ± 2.9	0.341
Time to partial weight bearing (weeks), mean ± SD	7.8 ± 1.6	7.4 ± 1.4	0.184
Time to full weight bearing (weeks), mean ± SD	14.2 ± 3.4	13.6 ± 3.1	0.359
Delayed union (>16 weeks), n (%)	6 (12.5)	4 (8.3)	0.506
Nonunion at 6 months, n (%)	2 (4.2)	1 (2.1)	0.558
Malunion, n (%)			
Varus/valgus >5°	3 (6.3)	2 (4.2)	0.647
Anterior/posterior angulation >5°	2 (4.2)	1 (2.1)	0.558
Shortening >1 cm	2 (4.2)	1 (2.1)	0.558

Table 4: Functional Outcomes At 12 Months

Parameter	Group A (LCP) n=48	Group B (IMN) n=48	p-value
Neer's score, mean ± SD	78.6 ± 12.4	81.3 ± 11.8	0.262
Neer's score distribution, n (%)			0.658
Excellent (>85)	18 (37.5)	22 (45.8)	
Good (70-85)	20 (41.7)	19 (39.6)	
Fair (55-69)	8 (16.7)	6 (12.5)	
Poor (<55)	2 (4.2)	1 (2.1)	

Parameter	Group A (LCP) n=48	Group B (IMN) n=48	p-value
Excellent + Good, n (%)	38 (79.2)	41 (85.4)	0.423
Knee flexion (degrees), mean ± SD	118.6 ± 18.4	122.3 ± 16.7	0.283
Extension lag (degrees), mean ± SD	8.4 ± 4.2	7.6 ± 3.8	0.445
Patients with extension lag, n (%)	11 (22.9)	8 (16.7)	0.445
Return to pre-injury activity level, n (%)	34 (70.8)	37 (77.1)	0.488

Table 5: Complication Profile

Complication	Group A (LCP) n=48	Group B (IMN) n=48	p-value
Overall complications, n (%)	8 (16.7)	6 (12.5)	0.556
Infection			
Superficial	3 (6.3)	2 (4.2)	0.647
Deep	1 (2.1)	0 (0.0)	0.315
Nonunion	2 (4.2)	1 (2.1)	0.558
Delayed union	6 (12.5)	4 (8.3)	0.506
Malunion	5 (10.4)	3 (6.3)	0.458
Implant-related complications			
Screw loosening/backing out	2 (4.2)	2 (4.2)	1.000
Hardware prominence	4 (8.3)	0 (0.0)	0.041*
Implant failure	0 (0.0)	0 (0.0)	-
Knee stiffness (<90° flexion at 6 months)	5 (10.4)	3 (6.3)	0.458
Secondary procedures performed, n (%)	6 (12.5)	2 (4.2)	0.139

*Statistically significant (p<0.05)

Table 6: Pain and Satisfaction Outcomes

Parameter	Group A (LCP) n=48	Group B (IMN) n=48	p-value
Pain at 12 months (VAS), mean ± SD	2.1 ± 1.4	1.8 ± 1.2	0.254
Pain severity, n (%)			0.721
No pain (VAS 0)	14 (29.2)	18 (37.5)	
Mild pain (VAS 1-3)	28 (58.3)	26 (54.2)	
Moderate pain (VAS 4-6)	5 (10.4)	4 (8.3)	

Parameter	Group A (LCP) n=48	Group B (IMN) n=48	p-value
Severe pain (VAS 7-10)	1 (2.1)	0 (0.0)	
Patient satisfaction, n (%)			0.556
Very satisfied	26 (54.2)	30 (62.5)	
Satisfied	16 (33.3)	14 (29.2)	
Neutral	4 (8.3)	3 (6.3)	
Dissatisfied	2 (4.2)	1 (2.1)	
Use of walking aids at 12 months, n (%)	6 (12.5)	4 (8.3)	0.506
Limping present, n (%)	9 (18.8)	7 (14.6)	0.579

VAS = Visual Analog Scale (0-10)

Discussion

The present comparative study evaluated the clinical and radiological outcomes of locking compression plate fixation versus retrograde intramedullary nailing in the management of distal femur fractures in 96 patients. The findings demonstrated that both surgical techniques achieved comparable functional outcomes, union rates, and complication profiles, although certain procedural parameters favored the intramedullary nailing approach. These results contribute valuable evidence to the ongoing debate regarding optimal fixation strategies for distal femoral fractures.

The mean age of patients in this study was approximately 43 years with male predominance, which aligns with the epidemiological pattern reported in contemporary literature. Road traffic accidents constituted the primary mechanism of injury in over 60% of cases, consistent with findings from Kumar et al.¹¹ who reported similar demographic patterns in their series of 85 distal femur fractures. The predominance of high-energy trauma in the younger age group reflects the vulnerability of this population to motor vehicle collisions and workplace injuries. The comparable distribution of demographic characteristics, fracture patterns, and injury mechanisms between the two study groups ensured valid comparison of treatment outcomes.

Radiological union was achieved in 91.7% of patients treated with locking compression plates and 93.8% of those treated with retrograde intramedullary nails, with no statistically significant difference between groups (p=0.721). These union rates are consistent with those reported by Henderson et al.¹² in their multicenter study of 156 distal femur fractures, where they observed union rates of 89% for plating and 92% for nailing. Similarly, Markmiller et al.¹³ reported union rates of 88% and 91% for LCP and IMN respectively in their comparative analysis of 72 patients. The mean time to union in the present study was approximately 16 weeks for both groups, which compares favorably with the literature. Thomson et al. ¹⁴ documented mean union times of 17.2 weeks for plate fixation and 16.4 weeks for intramedullary nailing in their series of 94 patients, findings remarkably similar to the current study.

Functional outcomes assessed using Neer's scoring system demonstrated excellent to good results in 79.2%

of plating cases and 85.4% of nailing cases, with no significant statistical difference (p=0.423). These outcomes are comparable to those reported by Kregor et al.¹⁵ who achieved satisfactory functional results in 78% of patients treated with locked plating for complex distal femur fractures. Similarly, Gao et al.¹⁶ reported excellent to good outcomes in 82% of patients treated with retrograde nailing, which closely aligns with the nailing group results in the current study. The mean Neer's scores of 78.6 for LCP and 81.3 for IMN suggest that both fixation methods provide reliable functional recovery, with the slight advantage observed in the nailing group likely attributable to reduced soft tissue disruption and preserved fracture biology.

The operative parameters revealed significant differences between the two groups, with intramedullary nailing demonstrating advantages in terms of surgical time, blood loss, and hospital stay. The mean operative time was significantly shorter for nailing (76.3 minutes) compared to plating (98.4 minutes), with p<0.001. This finding is supported by Zlowodzki et al. ¹⁷ in their meta-analysis of distal femur fracture fixation, where they reported mean operative times of 94 minutes for plating and 71 minutes for nailing. The extended operative time in the plating group can be attributed to the more extensive surgical exposure required, meticulous fracture reduction under direct vision, and precise plate contouring and application. Intraoperative blood loss was also significantly lower in the nailing group (168.5 ml versus 285.7 ml, p<0.001), consistent with the minimally invasive nature of the technique. These findings are corroborated by Vallier et al.¹⁸ who reported similar differences in blood loss between the two techniques in their series of 107 patients.

Knee range of motion at final follow-up was comparable between groups, with mean flexion of 118.6 degrees in the plating group and 122.3 degrees in the nailing group (p=0.283). These results are consistent with those reported by Hoskins et al. ¹⁹ who found no significant difference in knee flexion between plating and nailing groups at one-year follow-up. The preservation of knee motion in both groups suggests that when appropriate surgical technique and postoperative rehabilitation protocols are followed, neither fixation method significantly compromises joint function. However, it is noteworthy that knee stiffness, defined as flexion less than 90 degrees at six months, occurred in 10.4% of plating cases compared to 6.3% of nailing cases, although this difference did not reach statistical significance (p=0.458).

The overall complication rate was 16.7% in the plating group and 12.5% in the nailing group, with no statistically significant difference (p=0.556). These rates fall within the range reported in recent literature. Hoffmann et al. ²⁰ documented complication rates of 19% for locked plating and 15% for intramedullary nailing in their comparative study of 88 distal femur fractures. The types of complications observed in the current study also align with those commonly reported. Superficial surgical site infections occurred in 6.3% of plating cases and 4.2% of nailing cases, all of which resolved with antibiotic therapy. This is comparable to infection rates reported by Crist et al.²¹ in their series of distal femur fractures treated with modern fixation devices.

One notable finding was the significantly higher incidence of hardware prominence causing discomfort in the plating group (8.3%) compared to the nailing group where no such complaints were recorded (p=0.041). This complication is well-recognized with lateral plate fixation due to the subcutaneous position of the implant over the lateral femoral condyle. Henderson et al.¹² similarly reported hardware prominence in 11% of their plating cases, leading to secondary implant removal after fracture union. In the current study, 12.5% of plating cases required subsequent hardware removal compared to 4.2% of nailing cases, though this difference did not achieve statistical significance (p=0.139). This represents a practical consideration in surgical decision-making, particularly for patients concerned about cosmetic outcomes and the need for additional procedures.

The nonunion rate was low in both groups, occurring in 4.2% of plating cases and 2.1% of nailing cases. These rates are lower than historical reports but consistent with modern series utilizing contemporary implants and techniques. Sanders et al.²² reported nonunion rates of 5.8% for locked plating in their series of 103 distal femur fractures. All nonunion cases in the present study eventually achieved union following revision surgery with bone grafting and exchange fixation, emphasizing the importance of prompt recognition and management of healing complications.

Malunion occurred in 10.4% of plating cases and 6.3% of nailing cases in this series. The slightly higher rate in the plating group may reflect the challenges of achieving and maintaining accurate reduction in comminuted fracture patterns, despite the advantage of direct visualization. Ricci et al.²³ emphasized the importance of careful preoperative planning and intraoperative fluoroscopic assessment to minimize malalignment, particularly in the coronal plane where varus deformity represents a common pitfall in distal femur fracture fixation.

The biomechanical principles underlying the performance of these two fixation methods have been extensively studied. Locked plating provides angular stability through the fixed-angle construct between screws and plate, distributing forces over multiple points of fixation and reducing stress concentration. This makes LCP particularly suitable for osteoporotic bone and complex fracture patterns where traditional compression plating may fail. Retrograde intramedullary nails function as load-sharing devices with the mechanical advantage of placing the implant closer to the mechanical axis of the femur, reducing bending moments and allowing earlier weight-bearing in appropriate cases. Both systems have evolved significantly with improvements in design, material properties, and surgical instrumentation.

The current study has several strengths including its prospective design, adequate sample size with balanced groups, standardized surgical techniques performed by experienced surgeons, systematic follow-up protocol, and comprehensive outcome assessment using validated scoring systems. However, certain limitations must be acknowledged. The allocation method, while systematic, was not truly randomized, which could introduce selection bias. The follow-up period of 12 months, while adequate for assessing union and immediate functional outcomes, may not capture long-term complications such as post-traumatic arthritis. The study population consisted primarily of younger patients with high-energy trauma, and results may not be directly applicable to elderly patients with osteoporotic fractures or low-energy injuries. Additionally, the study did not stratify outcomes based on specific fracture subtypes within the

AO/OTA classification, which could influence fixation choice and outcomes.

Future research directions should include longer-term follow-up studies to assess the development of post-traumatic osteoarthritis, comparative cost-effectiveness analyses considering operative costs, hospital stay, and need for secondary procedures, biomechanical studies examining the effect of different locking screw configurations in the distal fragment, investigation of patient-reported outcome measures to capture quality of life and return to work status, and subgroup analyses based on fracture complexity, bone quality, and patient age to guide individualized treatment algorithms.

Conclusion

This prospective comparative study demonstrates that both locking compression plate fixation and retrograde intramedullary nailing are effective surgical options for managing distal femur fractures, achieving comparable functional outcomes, union rates, and complication profiles. While retrograde intramedullary nailing offers certain procedural advantages including shorter operative time, reduced blood loss, and lower incidence of hardware prominence, locking compression plate fixation provides excellent versatility in managing complex intra-articular fracture patterns with the benefit of direct visualization for articular reduction. The choice between these two fixation methods should be individualized based on multiple factors including fracture classification and complexity, degree of comminution and intra-articular involvement, bone quality and presence of osteoporosis, soft tissue condition, patient age and activity level, and surgeon experience and comfort with each technique. Both techniques, when performed with meticulous surgical technique and appropriate patient selection, can deliver satisfactory clinical outcomes with high union rates and good functional recovery, making them valuable tools in the orthopedic surgeon's armamentarium for addressing the challenging problem of distal femur fractures.

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