

Comparative Study of Distal Femoral Locked Plate Versus Retrograde Intra-Medullary Nailing in Fixation of Extra-Articular Distal Femur Fracture

Mohamed Moner Galhoom *, Atef Mohamed Morsy, Kareem Hamdy Ebada

Orthopedic Surgery Department, Faculty of Medicine, October 6th University.

Corresponding author: Mohamed Moner Galhoom, galhoom401@gmail.com

Abstract

Background

Extra-articular distal femoral fractures require stable fixation to restore alignment, promote union, and preserve knee function. Locked plating (LP) and retrograde intramedullary nailing (RIMN) are commonly used, although their relative clinical advantages remain uncertain.

Aim

To compare the operative, radiological, and functional outcomes of LP and RIMN in adults with extra-articular distal femoral fractures.

Patients and Methods: This retrospective comparative study included 98 patients aged 18–60 years with closed extra-articular distal femoral fractures treated at October 6 University Hospital between 2021 and 2025. Patients underwent LP (n = 58) or RIMN (n = 40). Operative duration, blood loss, postoperative pain, knee range of motion, weight-bearing ability, functional recovery, fracture union, deformity, reoperation, and complications were compared.

Results: LP patients were older (43.03 vs. 37.95 years, $P = 0.016$), with significantly different fracture morphology ($P < 0.001$). RIMN was associated with shorter operative duration (107.50 vs. 124.05 minutes, $P = 0.003$), lower blood loss (444.00 vs. 922.93 mL, $P < 0.001$), and lower median pain scores (1.5 vs. 2, $P < 0.001$). Bridging callus was more frequent after RIMN (95% vs. 22.41%, $P < 0.001$), with shorter mean union time (12.78 vs. 14.21 weeks, reported $P = 0.044$). Deformity patterns differed significantly ($P = 0.015$). Functional recovery, knee motion, weight-bearing ability, reoperation, and overall complication distributions showed no significant differences (all $P > 0.05$).

Conclusion: Both LP and RIMN achieved comparable recorded functional outcomes. RIMN showed favorable operative and healing outcomes, although baseline differences in age and fracture morphology limit causal interpretation.

Keywords: Distal femoral fractures; Locked plating; Retrograde intramedullary nailing; Fracture union; Functional outcome.

Introduction

Distal femoral fractures remain difficult injuries to manage because the fracture configuration, surrounding soft tissues, and mechanical demands of the knee can complicate both fixation and recovery. These injuries account for approximately 3% to 6% of femoral fractures and usually follow two different patterns of trauma. Younger adults commonly sustain high energy injuries, particularly road traffic accidents, whereas older patients may develop fractures after relatively minor falls, often in association with osteoporosis. The increasing frequency of fragility fractures has added to the clinical burden of distal femoral injuries [1,2].

For extra-articular fractures, the main objective of surgical treatment is to restore femoral length, rotation, and coronal and sagittal alignment while providing adequate stability for fracture healing. Early knee movement is equally important, as prolonged immobilization may contribute to stiffness, quadriceps weakness, and delayed functional recovery. Fixation can be particularly demanding in the distal metaphysis, where a relatively wide medullary canal, thin cortices, and variable comminution may compromise implant purchase. Muscle forces acting on the fracture fragments can also produce shortening, angulation, and rotational deformity, making satisfactory reduction and its maintenance essential [1,3].

Despite advances in implant design and surgical techniques, complications such as delayed union, nonunion, malalignment, infection, and restricted knee motion remain important concerns. Successful fixation therefore depends on more than mechanical stability alone. Preservation of fracture site vascularity, appropriate construct

stiffness, and sufficient interfragmentary movement for secondary bone healing also influence the final outcome. Patient characteristics, fracture morphology, and fixation strategy may further modify the risk of impaired union [3,4].

Distal femoral locked plating (LP) and retrograde intramedullary nailing (RIMN) are widely used for extra-articular distal femoral fractures. LP provides fixed-angle support through multiple screws placed in the distal fragment and permits fixation of fractures with short metaphyseal segments. It also allows direct correction of alignment when required. However, extensive exposure during conventional open plating may compromise the local biological environment, while an excessively rigid construct can interfere with callus formation. RIMN places the implant closer to the mechanical axis of the femur, reducing the bending moment acting on the fixation device. It may also limit soft tissue disruption, although adequate distal fixation, correct entry point selection, and avoidance of knee-related complications remain essential [3,5].

The comparative advantages of these techniques remain uncertain. Previous studies have reported differences in operative parameters, fracture union, functional recovery, and complications, although their findings have not consistently favored either fixation method [5-8].

Differences in fracture characteristics, patient selection, and outcome assessment across published studies leave uncertainty regarding the relative performance of LP and RIMN specifically in adult extra-articular distal femoral fractures.

Aim of the study: This study aimed to compare LP and RIMN in adult patients with extra-articular distal femoral fractures regarding operative duration, intraoperative blood loss, postoperative pain, knee range of motion, weight-bearing recovery, functional outcome, fracture union, deformity, reoperation, and complications.

Patients and Methods

Study Design and Setting

This retrospective comparative observational study included 98 adults who underwent surgical fixation for extra-articular fractures of the distal third of the femur at October 6 University Hospital, Egypt, between January 2021 and December 2025. The study compared clinical, operative, radiological, and functional outcomes following two fixation techniques. Retrospective data collection and analysis were undertaken over six months after ethical approval.

Eligibility Criteria

Patients aged 18–60 years with closed, extra-articular distal femoral fractures classified as type 33-A according to the Arbeitsgemeinschaft für Osteosynthesefragen/Orthopaedic Trauma Association (AO/OTA) classification were eligible. Patients with open or pathological fractures and those who were bedridden before injury were excluded.

Study Groups

The 98 eligible patients were categorized according to the fixation technique documented in their operative records. Group A (LP, n=58) comprised patients treated with lateral distal femoral locking plates, whereas Group B (RIMN, n=40) included those managed with retrograde femoral nails. Treatment allocation was not randomized, as the study evaluated previously performed surgical procedures.

Preoperative Assessment and Preparation

Hospital records were reviewed for age, sex, injury mechanism, fracture morphology, comorbidities, associated injuries, and general clinical status. Local findings included tenderness, swelling, deformity, soft tissue injuries, and the affected side. Plain radiographs were examined to characterize the fracture and document its configuration.

Before surgery, temporary stabilization was achieved using an above-knee back slab or skin traction, with analgesics administered as required. Enoxaparin was used for venous thromboembolism prophylaxis and withheld 12–24 hours preoperatively according to the institutional protocol.

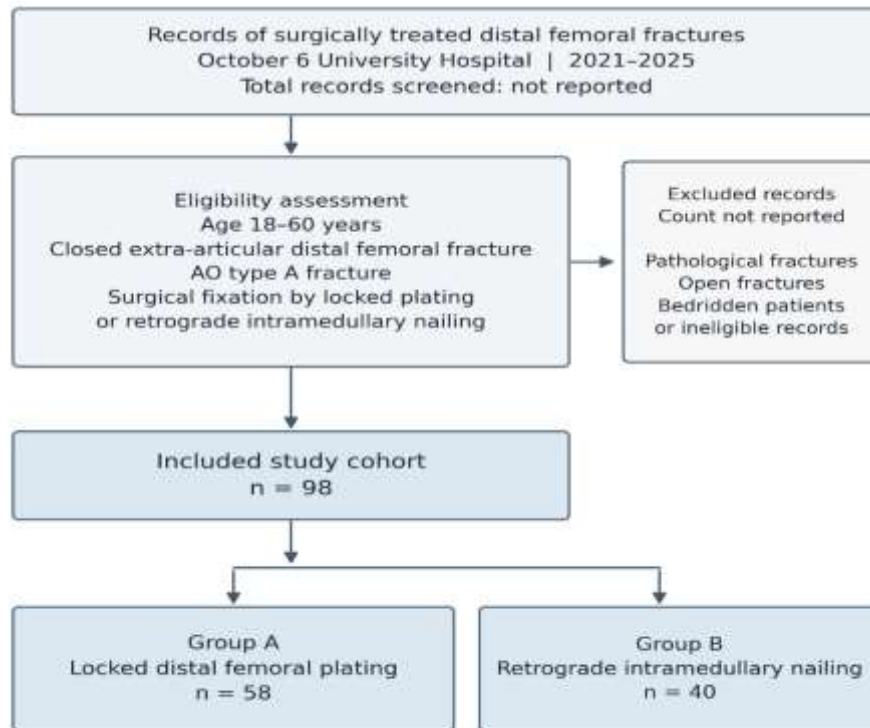


Figure 1. Patient selection for the retrospective comparison of locked distal femoral plating and retrograde intramedullary nailing. The included cohort comprised 98 patients, grouped according to the fixation technique received. AO, Arbeitsgemeinschaft für Osteosynthesefragen.

Surgical Procedures

Group A: Distal Femoral Locked Plating

With the patient supine on a radiolucent table, the knee was supported in approximately 30° of flexion. A lateral incision was made over the distal femur, and the vastus lateralis was elevated to expose the fracture while controlling perforating vessels. Following restoration of length, rotation, and alignment using traction and reduction instruments, the plate was applied to the lateral femoral surface.

Fluoroscopy guided plate positioning, particularly its relationship to the distal articular surface and anterior cortex. Fixation was obtained using appropriately directed screws in the proximal and distal fragments, with supplementary lag screws when required by fracture morphology. Final imaging confirmed reduction, implant position, and screw placement. After irrigation, a suction drain was inserted when indicated, followed by closure of the iliotibial band, subcutaneous tissues, and skin.

Group B: Retrograde Intramedullary Nailing

Patients were placed supine, and the distal femur was accessed through an anterior midline incision followed by a longitudinal split of the patellar tendon. The nail entry point was established under fluoroscopy in the intercondylar notch, centered on the anteroposterior projection and immediately anterior to the femoral attachment of the posterior cruciate ligament on the lateral projection, near the distal extension of Blumensaat's line.

After reduction, sequential canal reaming was performed to approximately 1–1.5 mm above the planned nail diameter. The selected nail was introduced with its curvature aligned to the femoral anatomy and seated beneath the articular surface. Proximal and distal interlocking screws secured the construct after fluoroscopic confirmation of satisfactory alignment and length. Implant position and knee movement were checked before irrigation and repair

of the patellar tendon and paratenon. The wound was closed without routine drain placement.

Reduction and Intraoperative Assessment

In both groups, reduction was facilitated by muscle relaxation, longitudinal traction, and posterior support beneath the distal fragment with the knee flexed approximately 30°. Manual manipulation, bone hooks, and reduction clamps were used when needed to correct displacement and angular or rotational deformity. Fluoroscopic assessment was performed before definitive fixation and at procedure completion. Operative duration and estimated intraoperative blood loss were extracted from the surgical records for comparison.

Postoperative Assessment and Follow-up

Postoperative evaluations were obtained from available inpatient and outpatient records. Pain intensity was assessed using the visual analogue scale (VAS), with scores from 0 indicating no pain to 10 representing the worst imaginable pain [9]. Wound condition, postoperative complications, and instructions regarding active knee exercises were also documented.

Knee range of motion (ROM) was evaluated in degrees from active extension to maximum flexion, with any extension deficit or lag recorded separately. Functional recovery was assessed through the documented clinical outcome and ability to bear weight. Weight-bearing status was reviewed in relation to rehabilitation progress and fracture healing. Radiographic follow-up included anteroposterior and lateral views to evaluate callus formation, progression toward union, residual deformity, and implant integrity. Time to union was obtained from the recorded clinical and radiological assessments. Limb shortening, malalignment, delayed union, malunion, infection, and subsequent surgical interventions were documented when reported. Reoperation was considered separately from other postoperative complications.

Study Outcomes

Operative outcomes comprised surgical duration and estimated blood loss. Clinical and functional outcomes included postoperative VAS score, wound status, knee ROM, weight-bearing ability, and recorded functional outcome. Radiological outcomes included evidence and timing of union, residual deformity, and limb shortening. Reoperation and postoperative complications were evaluated as additional safety outcomes.

Ethical Considerations

The study received approval from the Research Ethics Committee of the Faculty of Medicine, October 6 University. As the investigation involved retrospective examination of existing medical records, the requirement for individual informed consent was waived by the ethics committee. Patient information was anonymized through coded identifiers, with access restricted to the research team. Data confidentiality and handling followed institutional regulations and the ethical principles of the Declaration of Helsinki.

Statistical Analysis

Statistical analysis was performed using IBM SPSS Statistics, version 27 (IBM Corp., Armonk, NY, USA). Continuous variables were summarized as mean $\pm$ standard deviation or median and interquartile range, according to their distribution. Between-group comparisons used the independent-samples Student's t-test for normally distributed variables and the Mann-Whitney U test for nonnormally distributed variables. Categorical data were expressed as frequencies and percentages and compared using the Pearson chi-square test or Fisher's exact test when appropriate. All tests were two-sided, with $P < 0.05$ considered statistically significant.



Figure 2. Radiographic illustration of the fixation techniques described in Patients and Methods. (a) Anteroposterior and (b) lateral views of distal femoral locking plate fixation, (c) Anteroposterior and (d) lateral views of retrograde intramedullary nail fixation.

Results

Table 1. Demographic characteristics and fracture mechanism and morphology

Variable or category	Locked plating (n = 58)	Retrograde nailing (n = 40)	P value	Effect estimate (95% CI)
Age, years, mean $\pm$ SD	43.03 $\pm$ 10.1	37.95 $\pm$ 10.1	0.016*	MD 5.08 (1.37–8.80)
Age, years, range	25 - 60	23 - 59	—	—
Male	40 (68.97%)	26 (65%)	0.680	RR 1.06 (0.80–1.41)
Female	18 (31.03%)	14 (35%)	—	—
Mechanism of fracture: Fall on ground	13 (22.41%)	5 (12.5%)	0.082	—
Mechanism of fracture: Fall from height	9 (15.52%)	2 (5.0%)	—	—
Mechanism of fracture: Road traffic accident	36 (62.07%)	33 (82.5%)	—	—
Pattern of fracture: Oblique	19 (32.76%)	4 (10%)	<0.001*	—
Pattern of fracture: Spiral	8 (13.79%)	1 (2.5%)	—	—
Pattern of fracture: Comminuted	20 (34.48%)	0 (0%)	—	—

Variable or category	Locked plating (n = 58)	Retrograde nailing (n = 40)	P value	Effect estimate (95% CI)
Pattern of fracture: Wedge	3 (5.17%)	1 (2.5%)	—	—
Pattern of fracture: Comminuted, wedge	3 (5.17%)	1 (2.5%)	—	—
Pattern of fracture: Comminuted, oblique	2 (3.45%)	0 (0%)	—	—
Pattern of fracture: Transverse	2 (3.45%)	33 (82.5%)	—	—
Pattern of fracture: Segmental	1 (1.72%)	0 (0%)	—	—

Values are n (%) unless specified. MD, mean difference; RR, relative risk; CI, confidence interval; SD, standard deviation.

Table 2. General clinical findings and associated conditions

Variable or category	Locked plating (n = 58)	Retrograde nailing (n = 40)	P value
Fit and well	29 (50%)	25 (62.5%)	0.206
Polytrauma	7 (12.07%)	0 (0%)	—
Chest and head trauma	6 (10.34%)	7 (17.5%)	—
Hypertensive	8 (13.79%)	0 (0%)	—
Cardiac defect	3 (5.17%)	1 (2.5%)	—
Diabetic	2 (3.45%)	3 (7.5%)	—
Post concussion	4 (6.9%)	2 (5%)	—
Multiple contusions	2 (3.45%)	2 (5%)	—
Lower limb contusions	1 (1.72%)	0 (0%)	—
Lower limb laceration	1 (1.72%)	0 (0%)	—
Elbow fracture	1 (1.72%)	0 (0%)	—
Upper limb fractures	0 (0%)	1 (2.5%)	—
Distal radius fracture	0 (0%)	1 (2.5%)	—
Abdominal trauma, minor intraabdominal hemorrhage	1 (1.72%)	1 (2.5%)	—
Anxious	1 (1.72%)	0 (0%)	—
PTSD	1 (1.72%)	0 (0%)	—
Osteoporosis	1 (1.72%)	1 (2.5%)	—
Bronchial asthma	0 (0%)	1 (2.5%)	—

Values are n (%).

Table 3. Local clinical examination findings

Variable or category	Locked plating (n = 58)	Retrograde nailing (n = 40)	P value
Tender, swollen, deformed right femur	33 (56.9%)	33 (82.5%)	0.152
Tender, swollen, deformed left femur	19 (32.76%)	7 (17.5%)	—
Tender, swollen, deformed right distal femur	3 (5.17%)	0 (0%)	—
Tender, swollen, deformed right knee	2 (3.45%)	0 (0%)	—
Tender, swollen, deformed left distal femur	1 (1.72%)	0 (0%)	—

Values are n (%).

Table 4. Operative duration and intraoperative blood loss

Variable or category	Locked plating (n = 58)	Retrograde nailing (n = 40)	P value	Effect estimate (95% CI)
Operative time (min), mean $\pm$ SD	124.05 $\pm$ 28.04	107.5 $\pm$ 23.23	0.003*	MD 16.55 (7.08–26.02)
Operative time (min), range	70 - 180	70 - 180	—	—
Intraoperative blood loss (mL), mean $\pm$ SD	922.93 $\pm$ 131.91	444 $\pm$ 110.15	<0.001*	MD 478.93 (434.23–523.63)
Intraoperative blood loss (mL), range	700 - 1200	250 - 700	—	—

SD, standard deviation; MD, mean difference; CI, confidence interval. Positive MD indicates a higher value with plating. *Reported statistically significant result.

Table 5. Postoperative pain and wound condition

Variable or category	Locked plating (n = 58)	Retrograde nailing (n = 40)	P value
Post operative pain: Mild	20 (34.48%)	28 (70%)	0.014*
Post operative pain: Moderate	28 (48.28%)	9 (22.5%)	—
Post operative pain: Severe	10 (17.24%)	3 (7.5%)	—
VAS score, median	2	1.5	<0.001*
VAS score, IQR	2 - 3	1 - 2	—
Soaked dressing, intact wound, no discharge	29 (50%)	0 (0%)	<0.001*
Non soaked, intact wound, no discharge	2 (3.45%)	39 (97.5%)	—
Soaked dressing, intact wound, no signs of inflammation	15 (25.86%)	0 (0%)	—
Non soaked dressing, intact wound, no signs of inflammation	3 (5.17%)	0 (0%)	—
Clean, intact, non-soaked	6 (10.34%)	0 (0%)	—

Variable or category	Locked plating (n = 58)	Retrograde nailing (n = 40)	P value
Clean, intact, no signs of inflammation	1 (1.72%)	0 (0%)	—
Intact wound, serous discharge, redness	2 (3.45%)	1 (2.5%)	—

Values are n (%) except VAS median and interquartile range (IQR). VAS, visual analog scale. *Reported statistically significant result.

Table 6. Rehabilitation and functional recovery

Variable or category	Locked plating (n = 58)	Retrograde nailing (n = 40)	P value	Effect estimate (95% CI)
Education on active ROM exercises: completed	58 (100%)	40 (100%)	---	—
Knee ROM: Full range	47 (81.03%)	36 (90%)	0.453	RR 0.90 (0.77–1.06)
Knee ROM: Limited range	11 (18.97%)	4 (10%)	—	—
Ability to bear weight: Full weight bearing	47 (81.03%)	36 (90%)	0.453	RR 0.90 (0.77–1.06)
Ability to bear weight: Partial weight bearing	11 (18.97%)	4 (10%)	—	—
Functional outcome: Full function	47 (81.03%)	36 (90%)	0.453	RR 0.90 (0.77–1.06)
Functional outcome: Limited function	11 (18.97%)	4 (10%)	—	—

Values are n (%). ROM, range of motion; RR, relative risk; CI, confidence interval. RRs refer to full ROM, full weight bearing, and full function, respectively, comparing plating with nailing.

Table 7. Radiological callus formation and time to union

Variable or category	Locked plating (n = 58)	Retrograde nailing (n = 40)	P value	Effect estimate (95% CI)
Non-bridging callus	45 (77.59%)	2 (5%)	<0.001*	RR 15.52 (3.99–60.33)
Bridging callus	13 (22.41%)	38 (95%)	—	—
Time to union, weeks, mean $\pm$ SD	14.21 $\pm$ 3.71	12.78 $\pm$ 2.9	0.044*	MD 1.43 (0.21–2.66)
Time to union, weeks, range	10–26	10–22	—	—

Table 8. Deformity reoperation and postoperative complications

Variable or category	Locked plating (n = 58)	Retrograde nailing (n = 40)	P value
Deformity: Varus malalignment	7 (12.07%)	0 (0%)	0.015*
Deformity: Flexion deformity	4 (6.9%)	0 (0%)	—
Deformity: Extension deformity	0 (0%)	4 (10%)	—
Deformity: No	47 (81.03%)	36 (90%)	—

Variable or category	Locked plating (n = 58)	Retrograde nailing (n = 40)	P value
Incidence of reoperation: Yes	8 (13.79%)	1 (2.5%)	0.078
Incidence of reoperation: No	50 (86.21%)	39 (97.5%)	—
Complications: Malunion	10 (17.24%)	3 (7.5%)	0.283
Complications: Delayed union	1 (1.72%)	0 (0%)	—
Complications: Infection	3 (5.17%)	0 (0%)	—
Complications: No	44 (75.86%)	37 (92.5%)	—

Values are n (%). P values are overall comparisons for deformity, reoperation, and complications.

A total of 98 patients with extra-articular distal femoral fractures were included in this retrospective study. Of these, 58 underwent locked plating (LP), while 40 were managed using retrograde intramedullary nailing (RIMN).

Demographic Characteristics and Fracture Patterns

Patients treated with LP were significantly older than those who underwent RIMN (43.03 ± 10.1 vs. 37.95 ± 10.1 years, $P = 0.016$), whereas sex distribution was comparable ($P = 0.680$). Road traffic accidents were the predominant injury mechanism in both groups (62.07% and 82.5%, respectively), without a significant overall difference in injury mechanisms ($P = 0.082$). Fracture morphology differed significantly between groups ($P < 0.001$). Comminuted and oblique fractures were more frequent with LP (34.48% and 32.76%, respectively), while transverse fractures predominated in the RIMN group (82.5%) (Table 1).

General and Local Clinical Findings

General clinical findings and associated conditions showed no statistically significant overall difference between groups ($P = 0.206$). Most patients were classified as fit and well, representing 50% of the LP group and 62.5% of the RIMN group. Associated injuries and medical conditions varied across patients, including polytrauma, chest and head injuries, hypertension, and diabetes mellitus (Table 2).

Local examination findings were similarly distributed between groups ($P = 0.152$). Tenderness, swelling, and deformity involving the right femur constituted the most frequently recorded presentation, occurring in 56.9% of LP patients and 82.5% of RIMN patients. Left-sided femoral findings were documented in 32.76% and 17.5%, respectively (Table 3).

Operative Characteristics

Operative duration was significantly longer with LP than RIMN (124.05 ± 28.04 vs. 107.50 ± 23.23 minutes, $P = 0.003$), with a mean difference of 16.55 minutes (95% CI: 7.08–26.02). Intraoperative blood loss was also substantially greater in the LP group (922.93 ± 131.91 vs. 444.00 ± 110.15 mL, $P < 0.001$), corresponding to a mean difference of 478.93 mL (95% CI: 434.23–523.63) (Table 4).

Postoperative Pain and Wound Condition

Postoperative pain severity differed significantly between the two fixation groups ($P = 0.014$). Mild pain was more frequently reported following RIMN (70% vs. 34.48%), whereas moderate and severe pain were more common after LP. The median visual analogue scale score was significantly higher with LP than RIMN (2 [IQR: 2–3] vs. 1.5 [IQR: 1–2], $P < 0.001$). Wound condition also differed significantly ($P < 0.001$), with non-soaked, intact wounds without discharge documented in 97.5% of RIMN patients compared with 3.45% of LP patients. Most wound observations in the LP group were recorded under separate categories involving soaked dressings or clean, intact wounds (Table 5).

Rehabilitation and Functional Outcomes

All patients received education regarding active knee range-of-motion exercises. Full knee motion, unrestricted weight bearing, and full functional recovery were each reported in 81.03% of LP patients and 90% of RIMN patients. Although these outcomes numerically favored RIMN, none of the comparisons reached statistical significance (P_{1355}

0.453 for each outcome). Limited recovery in each category was documented in 18.97% and 10% of patients, respectively (Table 6).

Radiological Healing and Fracture Union

Bridging callus was more frequently documented following RIMN than LP (95% vs. 22.41%), while non-bridging callus was recorded in 5% and 77.59%, respectively ($P < 0.001$). The reported mean time to fracture union was also significantly shorter in the RIMN group (12.78 ± 2.90 vs. 14.21 ± 3.71 weeks, $P = 0.044$), with a mean difference of 1.43 weeks (95% CI: 0.21–2.66) (Table 7).

Deformity, Reoperation, and Complications

Postoperative deformity patterns differed significantly between groups ($P = 0.015$). Varus malalignment and flexion deformity were recorded exclusively following LP (12.07% and 6.9%, respectively), whereas extension deformity occurred only after RIMN (10%). Reoperation was more frequent with LP than RIMN (13.79% vs. 2.5%), although the difference was not statistically significant ($P = 0.078$). Similarly, the overall distribution of postoperative complications did not differ significantly ($P = 0.283$). Malunion was documented in 17.24% of LP patients and 7.5% of RIMN patients, while delayed union and infection were reported only in the LP group (1.72% and 5.17%, respectively) (Table 8).



Figure 3. Distal femoral locking plate fixation.



Figure 4. Anteroposterior (A) and lateral (B) radiographs illustrating retrograde intramedullary nail fixation of an extra-articular distal femoral fracture.

Discussion

Selecting the appropriate fixation method for extra-articular distal femoral fractures depends on fracture morphology, bone quality, and the stability needed for healing. LP provides fixed-angle support and facilitates reduction of complex metaphyseal fractures, while RIMN offers load-sharing fixation with less disruption of the surrounding soft tissues. Nauth et al. [16] discussed the importance of fracture biology and implant mechanics, while Greiwe and Archdeacon [17] described the advantages of locking plates in unstable and comminuted fractures.

The present study included 98 patients, with 58 treated by LP and 40 by RIMN. Patients in the LP group were significantly older (43.03 ± 10.1 vs. 37.95 ± 10.1 years, $P = 0.016$). Sex distribution and injury mechanism were comparable, while fracture patterns differed significantly ($P < 0.001$). Comminuted and oblique fractures were more frequent with LP, whereas transverse fractures predominated after RIMN (82.5%).

Partly agreeing with our findings, Singh et al. [11] reported a higher mean age after LP than RIMN (48.00 ± 15.65 vs. 40.43 ± 14.39 years), although the difference was not significant. El-Behairy et al. [8], in contrast, found comparable demographic characteristics. Yoon et al. [10], comparing 80 patients with complete intra-articular distal femoral fractures, also found no significant differences in age ($P = 0.32$), sex ($P = 0.57$), or injury mechanism ($P = 0.42$).

The greater fracture complexity in our LP group agrees with the principles discussed by Greiwe and Archdeacon [17], as locked plates provide angular stability and permit fixation of comminuted distal fragments. Zhu et al. [18] examined the mechanical behavior of elastic intramedullary nails in pediatric distal femoral fracture models and found that stability varied with fracture configuration. Although their results support the importance of fracture geometry, they cannot be directly applied to rigid RIMN in adults.

Preoperative Clinical Characteristics

General and local examination findings were comparable between groups ($P = 0.206$ and $P = 0.152$). Patients classified as fit and well represented 50% of the LP group and 62.5% of the RIMN group, while associated injuries and medical conditions varied.

Gao et al. [12] also assessed baseline characteristics in their comparison of 36 extra-articular distal femoral fractures. Shahzad et al. [19] used propensity matching to improve baseline comparability when evaluating LP and RIMN for periprosthetic distal femoral fractures. Their approach supports the importance of accounting for patient differences, although their fracture population was different from ours.

The nonsignificant clinical findings in the present study do not confirm complete baseline similarity. Differences in age and fracture morphology may have influenced surgical difficulty, healing, and postoperative recovery.

Operative Duration and Intraoperative Blood Loss

Operative time was significantly longer after LP than RIMN (124.05 ± 28.04 vs. 107.50 ± 23.23 minutes, $P = 0.003$). Blood loss was also greater with LP (922.93 ± 131.91 vs. 444.00 ± 110.15 mL, $P < 0.001$).

In agreement, El-Behairy et al. [8] reported longer operative duration and greater blood loss with LP ($P = 0.007$ and $P = 0.021$). Phanswal and Shuaib [13] similarly found shorter operative time after RIMN (77 ± 4 vs. 87.5 ± 5 minutes). Rajesh et al. [20] also reported more favorable early radiological outcomes following nailing in their comparison of 30 patients. Srikanth et al. [21] investigated both fixation methods in 60 adults, providing further comparative evidence regarding operative characteristics and recovery.

Conversely, Neradi et al. [14] reported pooled findings favoring LP for operative time and blood loss, while Aggarwal et al. [5], analyzing 936 patients, found no significant difference in operative duration. The variation across studies may be related to fracture complexity, reduction difficulty, surgical exposure, and implant characteristics.

In our cohort, the higher proportion of comminuted fractures treated by LP may have required greater exposure and manipulation. Therefore, the operative differences cannot be attributed entirely to the fixation method.

Postoperative Pain and Wound Condition

Pain intensity favored RIMN, with a lower median VAS score than LP (1.5 vs. 2, $P < 0.001$). Mild pain was more frequent after RIMN (70% vs. 34.48%, $P = 0.014$), while wound condition also differed significantly ($P < 0.001$).

Partly agreeing, Phanswal and Shuaib [13] reported fewer wound infections after RIMN. Their findings differed regarding knee pain, which was more frequent after nailing (38.42% vs. 12.5%). Singh et al. [11] similarly reported knee pain in 42.86% of patients treated with RIMN.

Lian et al. [22] reported a mean VAS score of approximately 2.1 at one year in patients undergoing retrograde nailing

with a double reverse traction repositr. Their findings are consistent with relatively low late pain scores after RIMN, although they did not compare the procedure directly with LP. Kishore et al. [23], studying 39 patients treated with RIMN, also assessed postoperative pain and knee function, showing the importance of monitoring knee symptoms after fixation.

The different pain findings may be explained by the site and timing of assessment. General postoperative pain may be lower after RIMN because of reduced surgical exposure, whereas anterior knee pain may develop from the nail entry site or local irritation. Aggarwal et al. [5] also reported lower infection rates following RIMN. However, dressing saturation in our study should not be considered evidence of infection without corresponding clinical findings.

Knee Motion, Weight Bearing, and Functional Recovery

Full knee ROM, full weight bearing, and full functional recovery were each documented in 81.03% of LP patients and 90% of RIMN patients, without statistically significant differences ($P = 0.453$).

In agreement, El-Behairy et al. [8] found comparable knee motion ($P = 0.146$). Dunbar et al. [6], in a multicenter randomized trial, also reported no significant difference in functional recovery. Phanswal and Shuaib [13] observed greater mean knee motion after RIMN (110° vs. 100°), although the difference was not significant.

In contrast to our nonsignificant weight-bearing findings, Phanswal and Shuaib [13] reported earlier full weight bearing following RIMN, achieved by 95% at 12 weeks compared with 72% after LP. Singh et al. [11] similarly found significantly earlier full weight bearing after nailing ($P = 0.004$).

Aggarwal et al. [5] reported better knee ROM following LP in their pooled analysis, differing from the numerical trend in our study. These differences may reflect variations in fracture severity, postoperative stability, rehabilitation, and assessment timing. The comparable functional outcomes in our cohort should also be interpreted cautiously because a validated functional scoring system was not specified.

Radiological Healing and Time to Union

Bridging callus was more frequent after RIMN than LP (95% vs. 22.41%, $P < 0.001$). Mean union time was also shorter after nailing (12.78 ± 2.90 vs. 14.21 ± 3.71 weeks, reported $P = 0.044$).

In agreement, Phanswal and Shuaib [13] reported earlier union following RIMN (11.85 ± 3.4 vs. 16.24 ± 7.4 weeks, $P < 0.05$). Singh et al. [11] also found significantly shorter union time after nailing ($P = 0.0006$). Said [15] described greater periosteal callus formation following intramedullary fixation, supporting the radiological pattern observed in our patients. Rajesh et al. [20] similarly reported more favorable early radiological findings after RIMN.

In contrast, Yoon et al. [10] found comparable union times after LP and RIMN (6.9 vs. 6.6 months, $P = 0.51$). Their study involved complete intra-articular fractures with metaphyseal comminution, which may account for the longer healing periods. Neradi et al. [14] and Aggarwal et al. [5] also found no significant pooled difference in union time, indicating that the healing advantage observed in our cohort was not consistent across larger studies.

Recent research has also addressed the influence of plating mechanics. Govindharaj et al. [24] studied 62 patients with comminuted distal femoral fractures and reported earlier union with optimized plate working length and screw density. Peterson et al. [25] observed nonunion in 16 of 81 plated fractures (19.75%). Nonunion was more frequent when four or more diaphyseal screws were used than when three were used (26.3% vs. 4.2%, $P = 0.038$). These findings support the importance of construct configuration in fracture healing.

RIMN provides load-sharing fixation that may allow controlled movement at the fracture site. Healing after LP is influenced by plate stiffness, fracture gap, working length, and medial cortical support. The greater fracture complexity in our LP group may have contributed to the observed difference in union time. In addition, the timing of radiological assessment was not specified, and the reported union-time P value requires confirmation.

Postoperative Deformity and Alignment

Deformity patterns differed significantly between groups ($P = 0.015$). Varus malalignment occurred in 12.07% of LP patients, and flexion deformity affected 6.9%. Extension deformity was documented in 10% following RIMN.

In contrast to our findings, Yoon et al. [10] reported a nonsignificant tendency toward varus deformity after RIMN. Phanswal and Shuaib [13] also documented malalignment in two nailed fractures. Neradi et al. [14] found no significant difference in malalignment between fixation methods.

Greiwe and Archdeacon [17] described the angular stability provided by locking plates, particularly in comminuted fractures. However, inadequate medial support may still permit varus collapse. With RIMN, inaccurate entry point placement, incomplete reduction, or inadequate distal fixation may produce angular deformity. Nauth et al. [16]

also discussed the importance of reduction quality and implant mechanics in maintaining fracture alignment. The different deformity patterns in our study may therefore reflect fracture configuration and technical factors rather than a consistent advantage of either fixation method.

Reoperation and Postoperative Complications

Reoperation occurred in 13.79% of LP patients and 2.5% after RIMN, without a significant difference ($P = 0.078$). Overall complication distributions were also comparable ($P = 0.283$). Malunion was more frequent numerically following LP (17.24% vs. 7.5%), while delayed union and infection were reported only in this group.

In agreement, Aggarwal et al. [5] found no significant overall differences in complications or reoperations, although infection and nonunion were less frequent following RIMN. Neradi et al. [14] and Dunbar et al. [6] also reported broadly comparable complication outcomes.

Shahzad et al. [19] reported comparable major outcomes between fixation methods in propensity-matched periprosthetic fracture cohorts, although implant-related complications differed. Their findings partly agree with ours, but direct comparison is limited by the presence of knee prostheses in their study population.

Phanswal and Shuaib [13] reported three nonunions and two delayed unions after LP compared with one nonunion following RIMN, agreeing with the numerical trend toward more healing complications after plating. Peterson et al. [25] and Govindharaj et al. [24] also identified construct-related factors associated with impaired healing after LP. Although reoperation was more frequent numerically after LP, the small number of events and lack of detailed revision indications prevent firm conclusions regarding comparative implant failure.

Clinical Implications

The present study suggests that RIMN may offer advantages in operative duration, blood loss, postoperative pain, and early radiological healing in selected extra-articular distal femoral fractures. LP remains useful for complex metaphyseal fractures requiring direct reduction and secure distal fixation.

Evidence from Dunbar et al. [6] and Aggarwal et al. [5] supports selecting the fixation method according to fracture morphology, bone quality, and reduction requirements rather than routinely favoring one implant. The differences observed in our cohort should be considered in relation to the greater fracture complexity among patients treated with LP.

Conclusion

Both locked distal femoral plating (LP) and retrograde intramedullary nailing (RIMN) provided comparable functional outcomes, knee range of motion, weight-bearing ability, and overall complication rates in adults with extra-articular distal femoral fractures. RIMN was associated with shorter operative duration, lower intraoperative blood loss, reduced postoperative pain, greater radiological bridging callus formation, and shorter time to union. Postoperative deformity patterns also differed significantly between the two techniques, while reoperation rates were comparable. Although these findings suggest potential advantages of RIMN, differences in baseline age and fracture morphology limit direct comparison. Implant selection should therefore be guided by fracture configuration, bone quality, and the requirements for stable fixation.

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