Original Research

COMPARATIVE STUDY OF LOCKING COMPRESSION PLATE VERSUS INTRAMEDULLARY NAILING IN EXTRA-ARTICULAR DISTAL TIBIA FRACTURES

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ABSTRACT

Background: Extra-articular distal tibia fractures pose significant surgical challenges given the unique anatomy of the metaphyseal-diaphyseal junction and the limited soft tissue envelope surrounding the distal leg. Two widely practiced surgical techniques, locking compression plate (LCP) fixation and intramedullary nailing (IMN), have both demonstrated effectiveness, yet continue to be debated regarding perioperative morbidity, radiological outcomes, and functional recovery.

Objectives: To compare LCP and IMN in terms of operative parameters, time to radiological union, functional recovery assessed by the American Orthopaedic Foot and Ankle Society (AOFAS) and Olerud-Molander Ankle Score (OMAS), and postoperative complications.

Methods: This prospective observational study enrolled 150 patients aged 18–70 years with extra-articular distal tibia fractures (AO/OTA type 43-A) treated at a tertiary care centre in Dindigul, Tamil Nadu, between January 2024 and January 2026. 80 Patients were managed with LCP and 70 with IMN. Outcome measures included operative time, estimated blood loss, hospital stay, fluoroscopy exposure, time to union, functional scores, alignment, and complications.

Results: IMN demonstrated significantly shorter operative time (74.2 ± 14.3 vs 98.4 ± 18.6 min, $p<0.001$), reduced blood loss (124.4 vs 182.6 mL, $p<0.001$), and shorter hospital stay (5.8 vs 7.6 days, $p<0.001$). Time to radiological union was shorter with IMN (16.4 vs 18.2 weeks, $p=0.003$). Mean AOFAS (85.1 vs 82.4, $p=0.04$) and OMAS (83.2 vs 79.6, $p=0.02$) scores were superior in the IMN group. On categorical functional grading, IMN yielded more excellent outcomes (27.1% vs 17.5%) and fewer fair/poor outcomes (10.0% vs 15.0%), though the overall distribution did not reach statistical significance ($p=0.23$). Combined excellent/good outcomes were 90.0% in IMN vs 85.0% in LCP ($p=0.31$). Complication rates were comparable between groups (34.3% vs 32.5%, $p=0.81$), though wound complications were more frequent with LCP and anterior knee pain was specific to IMN.

Conclusion: Both techniques provide satisfactory fixation for extra-articular distal tibia fractures. IMN offers advantages in perioperative morbidity and functional recovery, while LCP provides better coronal alignment control in multifragmentary patterns. Surgical decision-making should be individualised based on fracture morphology and the local soft tissue envelope.

Keywords: Distal Tibia Fracture, Locking Compression Plate, Intramedullary Nailing, AO/OTA 43-A, AOFAS Score, Olerud-Molander Score.

INTRODUCTION

Extra-articular fractures of the distal tibia, classified under AO/OTA type 43-A, represent one of the more demanding injury patterns encountered in orthopaedic trauma surgery.

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The distal tibial metaphysis is characterised by thin cortices, sparse cancellous bone, and a precarious soft tissue envelope that is prone to devascularisation following high-energy trauma. These anatomical constraints increase the risk of wound breakdown, infection, and delayed healing when surgical techniques do not adequately respect the biology of the injury zone [1].

The incidence of distal tibia fractures has risen steadily over recent decades, largely driven by road traffic accidents and falls from height mechanisms that predominate in the working-age population of India. Because these injuries disproportionately

affect economically productive individuals, optimising both the time to radiological union and the pace of functional restoration carries direct socioeconomic implications that extend well beyond the operating room [3]. Historically, open reduction and internal fixation using conventional plates was associated with high rates of wound complications and infection, leading surgeons to explore minimally invasive alternatives. The advent of locked plating technology, with its angular stability and the capacity for percutaneous insertion, substantially reduced the morbidity linked to extensive soft tissue stripping [4]. Intramedullary nailing, by virtue of its load-sharing biomechanics and minimal disruption of the periosteal blood supply, has also gained considerable acceptance for metaphyseal fractures, although the more angular metaphyseal anatomy of the distal tibia can challenge nail placement and alignment [5].

Several randomised and observational studies have attempted to resolve this debate with variable conclusions. A multicentre study by ***Vallier et al.*** [6] noted higher rates of malunion with nailing compared to plating, whereas the landmark TOSS trial [7] reported comparable functional outcomes at one year but greater wound complications in the plating cohort. Subsequent meta-analyses [8, 9] have consistently highlighted that no single technique is universally superior, and that outcomes are heavily influenced by fracture pattern, energy of injury, and the surgeon's familiarity with each implant system. Within the Indian subcontinent, where road traffic accidents generate a disproportionate burden of high-energy lower-limb injuries, data from tertiary care centres reflect a slightly different epidemiological profile from that described in Western literature. The prevalence of open fractures, comorbid conditions such as poorly controlled diabetes, and limited availability of early physiotherapy all influence the healing trajectory in ways that may not be fully captured by evidence derived from resource-rich settings. Against this background, the present study was designed to prospectively compare LCP fixation and IMN in patients with extra-articular distal tibia fractures managed at a tertiary orthopaedic unit in Dindigul, Tamil Nadu. The primary objective was to evaluate perioperative parameters, time to union, functional outcomes using AOFAS and OMAS, and the complication profile of both techniques over a two-year study window.

MATERIALS AND METHODS

Study Design and Setting

This was a prospective observational study conducted at the Department of Orthopaedics, a tertiary care centre in Dindigul, Tamil Nadu, India, over a two-year period from January 2024 to January 2026. The study was approved by the Institutional Ethics Committee and conducted in accordance with the Declaration of Helsinki. Written informed consent was obtained from all participants prior to enrolment.

Inclusion Criteria

1. Patients between 18 and 70 years of age.
2. Presented with extra-articular distal tibia fractures (AO/OTA classification type 43-A).
3. Willing to attend all follow-up visits.

Exclusion Criteria

1. Fractures involving the articular surface (AO/OTA types 43-B and 43-C).
2. Pathological fractures.
3. Fractures in patients with uncontrolled systemic comorbidities that preclude surgery.
4. Patients with neurovascular injuries requiring vascular reconstruction.
5. Revision cases (previously surgically treated for the same fracture).
6. Bilateral fractures.
7. Prior history of surgically treated ipsilateral lower-limb injury.

Patient Allocation and Surgical Technique

Allocation to LCP or IMN was based on clinical and fracture morphological considerations assessed by the treating surgeon rather than by randomization. Fractures with significant metaphyseal comminution close to the articular margin and those with concomitant fibular fractures requiring plate stabilization were preferentially treated with LCP. More diaphyseal-extending and simpler metaphyseal patterns were directed toward IMN. This pragmatic allocation mirrors real-world surgical decision-making at the study centre. All LCP procedures were performed under spinal anaesthesia using a standard anterolateral or anteromedial approach. A 3.5 mm or 4.5 mm distal tibial locking plate was contoured as necessary and applied using the minimally invasive plate osteosynthesis (MIPO) technique, ensuring that a minimum of three bicortical screws were placed proximal to the fracture zone. The fibula was plated first when co-existing fibular fractures were present to assist in length restoration.

IMN was performed in a semi supine position using a suprapatellar or infrapatellar approach, based on surgeon preference. Reaming was performed in all cases. Proximal and distal interlocking screws were placed using a freehand technique under fluoroscopic guidance. Blocking screws were utilized in cases where the distal metaphyseal fragment showed a tendency to angulate during nail passage.

Postoperative Management

All patients received a standardized postoperative protocol consisting of intravenous antibiotics for 48 hours, low-molecular-weight heparin thromboprophylaxis, and supervised physiotherapy commencing on the first postoperative day. Partial

weight-bearing with crutch assistance was initiated at four to six weeks after clinical and radiological assessment. Progressive full weight-bearing was permitted once bridging calluses were evident on at least three cortices on orthogonal radiographs. Wound status, implant position, and fracture alignment were assessed at 2, 6, 12, and 24 weeks postoperatively.

Outcome Measures

Operative parameters recorded included surgical duration (minutes), estimated intraoperative blood loss (mL), duration of fluoroscopy exposure (minutes), and length of hospital stay (days). Radiological outcomes comprised the time to cortical union (weeks), rates of delayed union (defined as absence of radiological union at 20 weeks), non-union (absence of union at 36 weeks), and malunion (coronal or sagittal angulation exceeding five degrees on final radiograph). Functional outcomes were evaluated using the AOFAS Ankle-Hindfoot Scale and the Olerud-Molander Ankle Score (OMAS) at 24 weeks. Ankle range of motion was measured using a standard goniometer. Patient satisfaction was recorded as very satisfied, satisfied, or unsatisfied. Overall functional grading was assigned as excellent (>90), good (75–90), fair (60–74), or poor (<60) based on AOFAS score.

Statistical Analysis

Data were entered into Microsoft Excel and analysed using SPSS version 26.0. Continuous variables are expressed as mean ± standard deviation. Categorical variables are presented as frequencies and percentages. Independent samples t-test was used for comparison of continuous variables, and the chi-square test or Fisher's exact test was applied for categorical data as appropriate. A p-value of less than 0.05 was considered statistically significant.

RESULTS

Baseline Demographics

A total of 150 patients fulfilled the eligibility criteria and were enrolled over the study period. 80 patients underwent LCP fixation and 70 received IMN. The mean age was 41.3 ± 11.2 years in the LCP group and 39.8 ± 10.6 years in the IMN group (p=0.38). The overall sex distribution was 103 males and 47 females, with no statistically significant difference between groups (p=0.92). Road traffic accidents were the predominant mechanism of injury in both cohorts, accounting for 65.0% of LCP and 62.9% of IMN cases. Open fractures were present in 17.5% of LCP and 14.3% of IMN patients (p=0.61). Table 1 summarizes the baseline demographics.

Table 1. Baseline Demographics and Preoperative Characteristics

Variable	LCP Group (n=80)	IMN Group (n=70)	Total (N=150)	p-value
Mean Age (years)	41.3 ± 11.2	39.8 ± 10.6	40.6 ± 10.9	0.38
Male / Female	54 / 26	49 / 21	103 / 47	0.92
Right Side	46 (57.5%)	38 (54.3%)	84 (56.0%)	0.71
Road Traffic Accident	52 (65.0%)	44 (62.9%)	96 (64.0%)	0.79
Open Fracture	14 (17.5%)	10 (14.3%)	24 (16.0%)	0.61

Values as mean ± SD or n (%). No significant between-group difference in baseline characteristics.

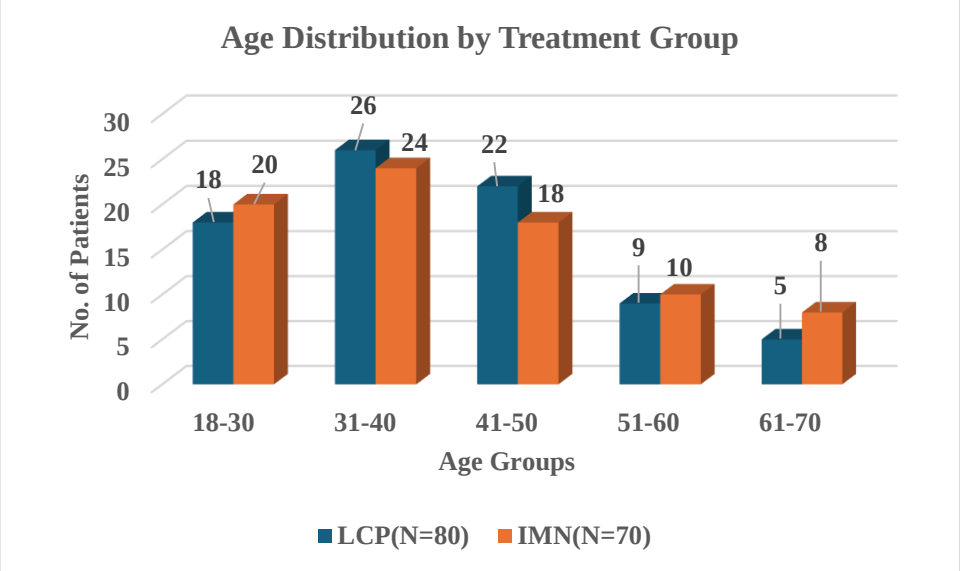


Figure 1. Age Distribution across Five Age Groups in Both Treatment Arms

Fracture Classification

The AO/OTA 43-A2 pattern was the most frequent subtype in both groups (38.8% LCP; 42.9% IMN), followed by 43-A1 (35.0% LCP; 31.4% IMN) and 43-A3 (26.3% LCP; 25.7% IMN). The distribution was comparable between groups ($p>0.05$), confirming that the two cohorts were well-matched for fracture severity. Table 2 presents the classification data; the proportional distribution is also illustrated in Figure 2.

Table 2. AO/OTA Fracture Classification Distribution

Fracture Type	LCP n (%)	IMN n (%)	Total n (%)	p-value
43-A1 (Simple)	28 (35.0)	22 (31.4)	50 (33.3)	0.64
43-A2 (Wedge)	31 (38.8)	30 (42.9)	61 (40.7)	0.61
43-A3 (Comminuted)	21 (26.3)	18 (25.7)	39 (26.0)	0.94

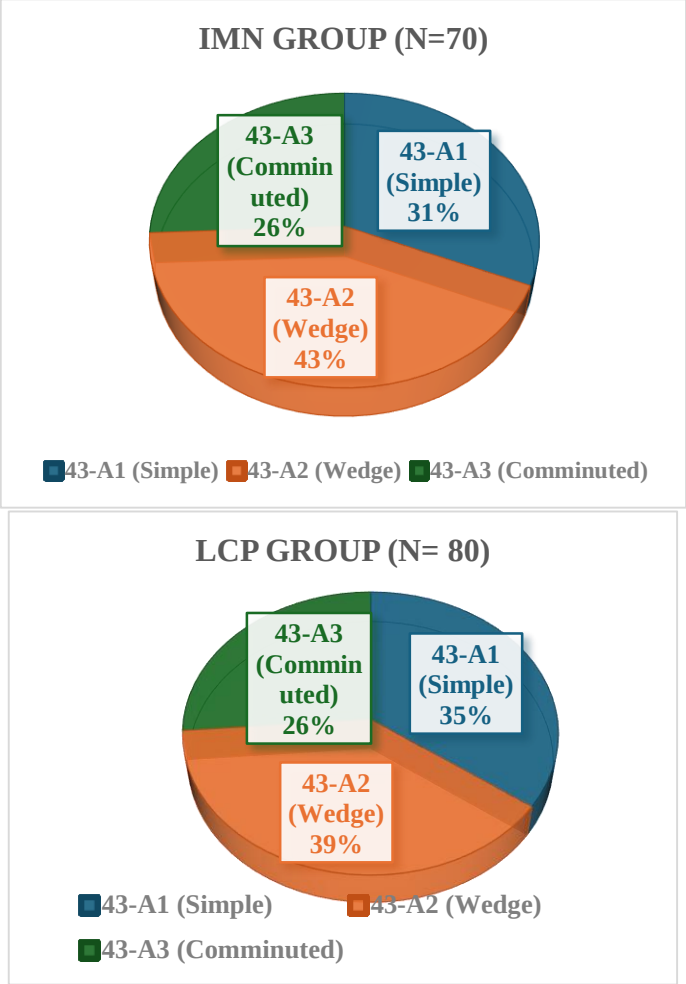


Figure 2. AO/OTA Fracture Subtype Proportions in LCP and IMN Groups

Operative Variables

IMN was associated with significantly shorter operative time (74.2 ± 14.3 vs 98.4 ± 18.6 minutes, $p<0.001$) and notably lower intraoperative blood loss (124.4 ± 38.2 vs 182.6 ± 44.8 mL, $p<0.001$). Hospital stay was shorter in the IMN cohort (5.8 ± 1.8 vs 7.6 ± 2.1 days, $p<0.001$). Fluoroscopy exposure time, however, was significantly greater in the IMN group (6.4 ± 1.6 vs 4.8 ± 1.2 minutes, $p<0.001$), reflecting the technical demands of distal interlocking screw placement. These findings are detailed in Table 3.

Table 3. Comparison of Operative Variables

Operative Parameter	LCP (Mean ± SD)	IMN (Mean ± SD)	p-value
Operative Time (min)	98.4 ± 18.6	74.2 ± 14.3	< 0.001
Estimated Blood Loss (mL)	182.6 ± 44.8	124.4 ± 38.2	< 0.001

Fluoroscopy Time (min)	4.8 ± 1.2	6.4 ± 1.6	< 0.001
Hospital Stay (days)	7.6 ± 2.1	5.8 ± 1.8	< 0.001

Statistically significant (p<0.05). SD = standard deviation.

Radiological and Functional Outcomes

Radiological union was achieved at a mean of 16.4 ± 2.1 weeks in the IMN group compared to 18.2 ± 2.6 weeks in the LCP group (p=0.003). Delayed union occurred in 5.7% of IMN and 8.8% of LCP patients; non-union rates were 2.9% and 3.8%, respectively, with neither difference reaching statistical significance. Malunion, defined as more than five degrees of coronal or sagittal angulation, was observed in 4.3% and 5.0% of cases in the respective groups (p=0.83). Satisfactory coronal alignment was achieved in the majority of patients in both cohorts. Functional scores at six months demonstrated a modest but statistically significant advantage for IMN. The mean AOFAS score was 85.1 ± 7.9 in the IMN group versus 82.4 ± 8.6 in the LCP group (p=0.04). The OMAS showed a similar pattern (83.2 ± 8.4 vs 79.6 ± 9.2, p=0.02). Full weight-bearing was achieved approximately 1.6 weeks earlier in the IMN cohort (11.2 vs 12.8 weeks, p=0.001). Regarding AOFAS-based functional grading, in the LCP group, 14 patients (17.5%) had excellent outcomes, 54 (67.5%) good, 10 (12.5%) fair, and 2 (2.5%) poor. In the IMN group, 19 patients (27.1%) had excellent outcomes, 44 (62.9%) good, 6 (8.6%) fair, and 1 (1.4%) poor. The distribution of functional grades showed a trend favoring IMN but did not reach statistical significance (p=0.23). Table 4 and Figure 3 present the detailed outcome comparison.

Table 4. Radiological and Functional Outcome Comparison at 24 Weeks

Outcome Measure	LCP	IMN	p-value
Time to Union (weeks)	18.2 ± 2.6	16.4 ± 2.1	0.003
Full Wt Bearing (weeks)	12.8 ± 1.9	11.2 ± 1.7	0.001
AOFAS Score (mean)	82.4 ± 8.6	85.1 ± 7.9	0.04
OMAS Score (mean)	79.6 ± 9.2	83.2 ± 8.4	0.02
Delayed Union	7 (8.8%)	4 (5.7%)	0.46
Non-union	3 (3.8%)	2 (2.9%)	0.74
Malunion	4 (5.0%)	3 (4.3%)	0.83
Functional Grading (AOFAS)			0.23
Excellent (>90)	14 (17.5%)	19 (27.1%)	
Good (75–90)	54 (67.5%)	44 (62.9%)	
Fair (60–74)	10 (12.5%)	6 (8.6%)	
Poor (<60)	2 (2.5%)	1 (1.4%)	
Excellent/Good Outcome	68 (85.0%)	63 (90.0%)	0.31

Statistically significant (p<0.05). AOFAS = American Orthopaedic Foot and Ankle Society; OMAS = Olerud-Molander Ankle Score.

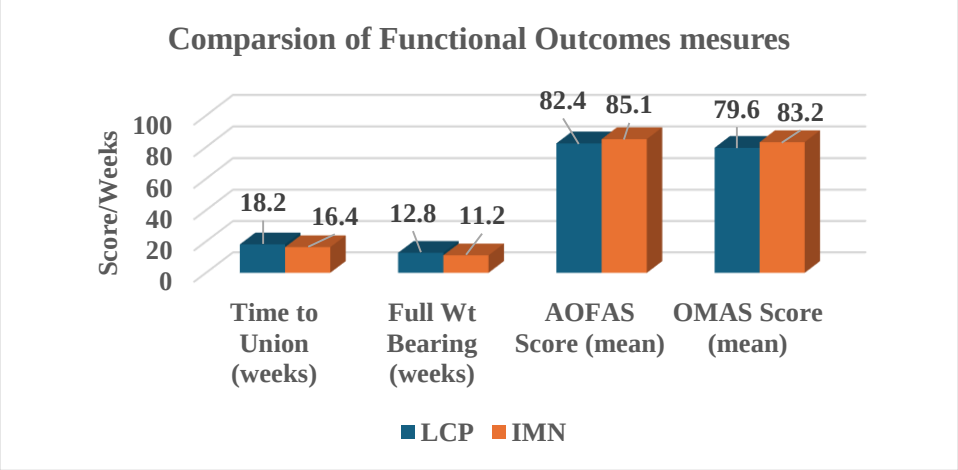


Figure 3. Comparative Functional Outcome Measures — AOFAS, OMAS, Time To Union, and Full Weight-Bearing

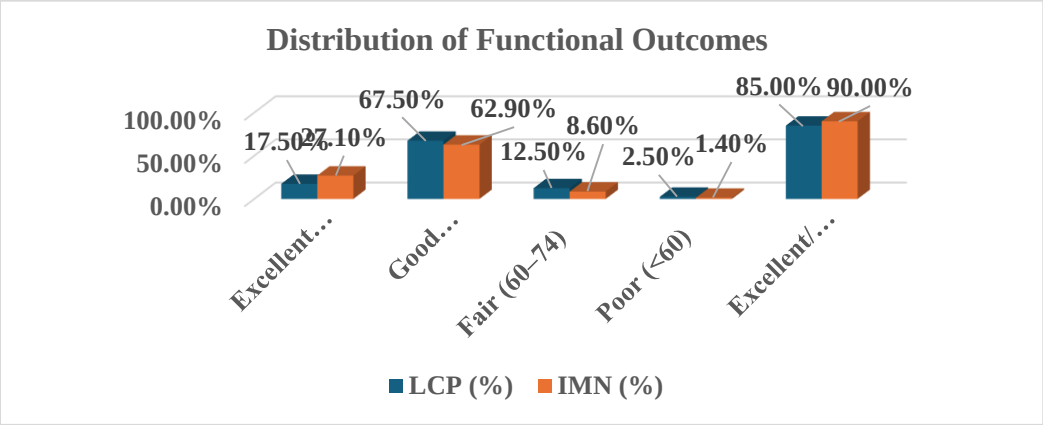


Figure 4. Distribution of Functional Outcomes (AOFAS Grading) In LCP and IMN Groups

Complications

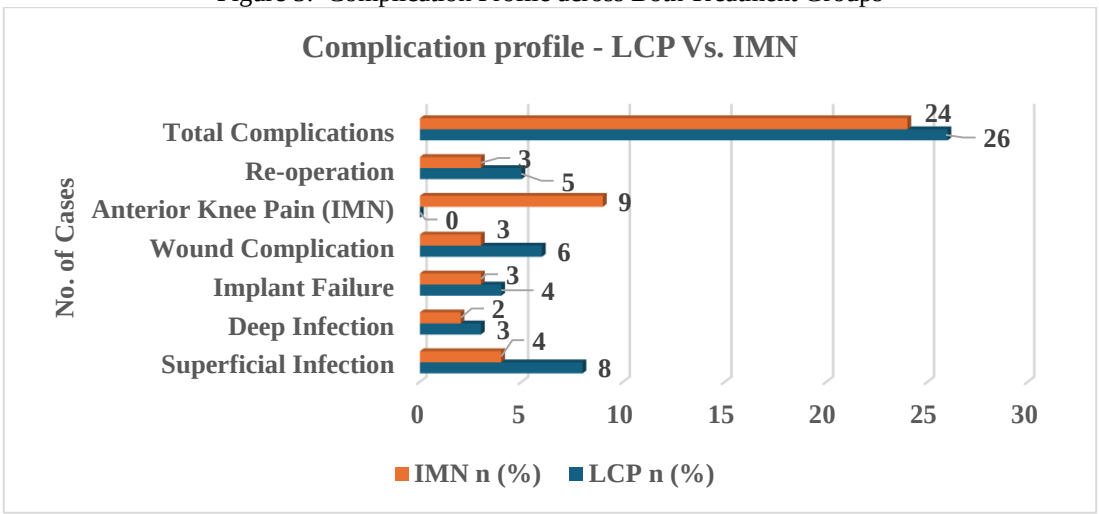
Overall complication rates were 32.5% in the LCP group and 34.3% in the IMN group (p=0.81). Wound-related complications, including superficial infection (10.0% vs 5.7%) and wound dehiscence (7.5% vs 4.3%), occurred more frequently with LCP. Deep infection rates were similarly low in both groups (3.8% vs 2.9%). Implant failure requiring revision was recorded in four LCP and three IMN patients. Anterior knee pain was a complication unique to the IMN group, affecting 9 patients (12.9%). Re-operation was necessary in five LCP (6.3%) and three IMN (4.3%) patients. Table 5 and Figure 5 illustrate the full complication profile.

Table 5. Postoperative Complication Profile

Complication	LCP n (%)	IMN n (%)	Total n (%)	p
Superficial Infection	8 (10.0)	4 (5.7)	12 (8.0)	0.33
Deep Infection	3 (3.8)	2 (2.9)	5 (3.3)	0.75
Implant Failure	4 (5.0)	3 (4.3)	7 (4.7)	0.83
Wound Complication	6 (7.5)	3 (4.3)	9 (6.0)	0.42
Anterior Knee Pain (IMN)	N/A	9 (12.9)	9 (6.0)	—
Re-operation	5 (6.3)	3 (4.3)	8 (5.3)	0.57
Total Complications	26 (32.5)	24 (34.3)	50 (33.3)	0.81

N/A = not applicable to that surgical group. No statistically significant difference in overall complication rate between groups.

Figure 5. Complication Profile across Both Treatment Groups



DISCUSSION

The management of extra-articular distal tibia fractures continues to generate lively debate in orthopaedic literature, and the findings from this prospective study add contemporary data from an Indian tertiary care setting to the existing body of evidence. Both LCP and IMN yielded satisfactory outcomes across the majority of patients, yet several statistically significant differences emerged that carry meaningful clinical implications. The perioperative advantage of IMN observed in this study shorter operative time, reduced blood loss, and briefer hospital stay aligns well with the mechanistic rationale underlying closed nailing techniques. Because the intramedullary approach avoids wide soft tissue dissection, it preserves the periosteal vascularity that is essential for fracture healing in a zone already compromised by the original injury. This is consistent with findings reported by ***Guo et al.*** [12], who in a systematic review of 1,702 patients noted that IMN was associated with significantly lower wound complication rates compared to plating. Similarly, ***Mauffrey et al.*** [13] observed that operative time with IMN averaged nearly 25 minutes less than with plate fixation in metaphyseal tibia fractures, a figure closely mirroring our observation of a 24-minute difference. The superior AOFAS and OMAS scores recorded in the IMN group at six months, while statistically significant, merit careful interpretation. A mean difference of 2.7 points on the AOFAS and 3.6 points on the OMAS, though measurable, may not reach the threshold of the minimal clinically important difference (MCID) for these instruments, which has been estimated at approximately five points for the AOFAS [14]. Notwithstanding, the consistently superior functional trajectory in the IMN cohort, including earlier full weight-bearing by approximately 1.6 weeks, suggests a genuine biological and biomechanical advantage that could translate into faster return to daily activities in a working-age population. When examining categorical functional grades, the IMN group had a higher proportion of excellent outcomes (27.1% vs 17.5%) and a lower proportion of fair/poor outcomes (10.0% vs 15.0%), although this difference did not reach statistical significance, possibly due to sample size.

The time to radiological union was statistically shorter with IMN (16.4 vs 18.2 weeks), a finding that reinforces the load-sharing biomechanical profile of nails relative to the load-bearing nature of lateral plates. Several authors, including ***Nork et al.*** [15] and ***Lindvall et al.*** [16], have described slower callus maturation with plate fixation, particularly when the plate acts as an absolute stability construct that suppresses interfragmentary motion and the associated periosteal callus response. In the present cohort, delayed union was more frequent in the LCP group (8.8% vs 5.7%), though this did not attain statistical significance, possibly owing to sample size limitations. Wound-related morbidity was a more prominent concern in the LCP group, with superficial infection and wound dehiscence rates that were approximately twice those observed with IMN. This finding echoes the TOSS trial [7] and corroborates a pooled analysis by ***Gurisk et al.*** [17], both of which identified wound complications as the principal disadvantage of plate fixation at the distal tibia. The thin skin over the anteromedial tibial surface affords little biological buffer against incisional tension, haematoma, and the revascularizing effect of subperiosteal dissection. The adoption of MIPO principles in this study partially mitigated this risk, yet the soft tissue concern remained measurable.

Anterior knee pain, affecting 12.9% of IMN patients, represents a recognized and incompletely resolved complication of tibial nailing. The suprapatellar technique has been proposed as a means of reducing patellar tendon irritation, and its selective use in this study may have partially attenuated what could otherwise have been a higher incidence [18]. Anterior knee pain was not observed in any LCP patient, confirming its specificity to the nailing approach and reinforcing the need for explicit preoperative patient counselling when IMN is selected. The overall complication rates were comparable between groups (32.5% LCP vs 34.3% IMN, p=0.81), suggesting that the complication burden, while differing qualitatively in character, is broadly equivalent in magnitude. Surgeons must therefore weigh the wound-centric risk profile of plating against the knee-pain-related morbidity of nailing when counselling individual patients. A notable strength of this study is its prospective design, allowing systematic capture of all perioperative and follow-up data at pre-specified time points. The use of two validated functional instruments, AOFAS and OMAS, provides multi-dimensional assessment of recovery. Limitations include the non-randomized allocation, which may introduce selection bias, and the follow-up window of six months, which may not capture late complications such as implant prominence, delayed malunion correction, or long-term arthritic change. A larger, randomized trial with at least two-year follow-up and patient-reported outcome measures would further consolidate these findings.

CONCLUSION

This prospective comparative study demonstrates that both locking compression plate fixation and intramedullary nailing provide effective surgical solutions for extra-articular distal tibia fractures. Intramedullary nailing offers measurable

advantages in terms of operative efficiency, reduced perioperative morbidity, earlier radiological union, and superior functional scores at six months. However, anterior knee pain remains a procedure-specific concern that requires preoperative discussion. Locking compression plate fixation retains value in multi-fragmentary patterns with close articular proximity, in open fractures with compromised intramedullary access, and in situations where precise coronal alignment control is paramount. The qualitatively distinct complication profiles of these two techniques underscore that neither intervention is universally superior, and that fracture morphology, soft tissue status, patient activity demands, and surgeon expertise should collectively guide implant selection.

Future well-powered randomized controlled trials with extended follow-up and incorporation of patient-reported outcomes are warranted to provide definitive evidence for evidence-based guidelines in this challenging fracture category.

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Conflict Of Interest

The authors declare no conflict of interest pertaining to this study. The implant systems used were selected solely on clinical grounds without any financial relationship with manufacturers.

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