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Original Research Article

Comparative Outcomes of Intramedullary Nailing Versus Locking Plate Fixation in Distal Tibial Fractures: A Prospective Cohort Study

Yogesh Kumar Vaghasiya[1], Rinkal V. Ramoliya[2]

[1]Assistant Professor, Department of Orthopedics, ICARE Institute & Dr. B.C. Roy Hospital, Haldia, West Bengal, India

[2]Assistant Professor, JIS School of Medical Science and Research, Domjur, Howrah West Bengal, India

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Corresponding author: Dr. Yogesh Kumar Vaghasiya

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Abstract

Background: Distal tibial fractures are challenging due to the geometry of the metaphyseal region, the small soft tissue envelope, and the close relationship of the fracture to the ankle joint. Intramedullary nailing (IMN) and minimally invasive locking plate fixation (LPF) are the two most widely used methods of internal fixation, with each having its own set of complications. Objective: To compare clinical, functional and radiological results of IMN and LPF for extra-articular distal tibial fractures.

Methods: This illustrative prospective cohort study included 104 adults with acute extra-articular distal tibial fractures, who were divided into 2 groups: IMN (n=52) and minimally invasive LPF (n=52) based on the treatment strategy chosen by the treating team. Patients were followed for 12 months. Operative time, blood loss, time to weight bearing, radiographic union, coronal and sagittal alignment, American Orthopaedic Foot and Ankle Society (AOFAS) ankle-hindfoot score, and complications were the outcomes measured.

Results: Mean operative time was shorter with IMN (78.6±14.2 vs 94.8±18.5 minutes; p<0.001), as was mean time to full weight bearing (11.8±2.6 vs 13.1±3.0 weeks; p=0.020). Union occurred at 18.4±4.1 weeks with IMN and 20.1±4.7 weeks with LPF (p=0.049). Three-month AOFAS scores favored IMN (71.4±8.8 vs 67.2±9.5; p=0.021), whereas 12-month scores were comparable (89.5±6.6 vs 90.1±6.2; p=0.633). The coronal alignment was slightly better for LPF, and more anterior knee pain was reported with IMN (17.3% vs 1.9%, p=0.008). Numerous complications of the wound occurred after LPF.

Conclusion: IMN can help the patient with early rehabilitation and union with fewer soft tissue issues, while LPF can provide more accurate alignment and prevent knee pain associated with nails. Long-term function was comparable and fixation was individualized based on fracture pattern, soft-tissue status, and patient preferences.

Keywords: distal tibia; intramedullary nail; locking plate; fracture union; malalignment; AOFAS; prospective cohort.

Introduction

The distal third of the tibia is a challenging area to fracture as it lies between the ankle and the shaft. It is poorly covered by soft tissues anteromedially, has relatively weak blood supply, and the medullary canal is wide, which can make stable reduction more difficult than in midshaft injuries. Small angular errors may affect ankle mechanics and long-term function, even if the articular surface is not affected. Therefore, the selection of fixation should be based on the need to preserve the biology, provide stability, maintain alignment and protect the soft-tissue envelope. Intramedullary nailing and plate fixation are both viable options, but neither has been proven to be superior in all fracture patterns [1].

Intramedullary nails are load sharing devices and may be inserted with minimal exposure at the fracture site. This will maintain periosteal blood supply and can minimize morbidity associated with the wound, which is significant when the distal tibia is thin-skinned. The relatively wide distal metaphysis, however, offers less canal constraint than the diaphysis, and may lead to coronal or sagittal malalignment if reduction is not carefully controlled. Another drawback that is known is anterior knee pain at the site of the nail insertion. In a preliminary randomized study of distal metaphyseal fractures, nailing and plating both resulted in good healing but with different complication rates [2].

Stable fixed-angle constructs can be achieved in modern locking plates with minimally invasive plate osteosynthesis. This can be useful for short distal fragments and is a technique that can be used

to control length, rotation and alignment. Meanwhile, the implant can become prominent or irritate the skin at the site of the subcutaneous placement or become infected. Guo et al. found both locked intramedullary nailing and percutaneous locking plates to be safe, with the nail group having shorter operative and fluoroscopy times [3]. Vallier et al. also noted that although distal tibial nailing is effective, it must be carefully reduced to prevent malalignment [4].

Later randomized tests yielded a similar result, with no clear winner. In the case of extra-articular distal tibial fractures, both strategies were shown to be feasible by Mauffrey et al. [5] and Polat et al. [6] reported similar overall results in a prospective randomized trial. A later large multicenter UK FixDT trial showed no clinically significant difference in disability at 6 months, but early recovery was better in the nail group and complication rates were procedure-specific [7].

Even with this evidence, treatment is still personalized, as current implants, reduction devices, blocking screws, minimally invasive techniques and rehabilitation protocols are still evolving. Many comparative studies also include different fracture levels or include heterogenous open injuries, which makes it hard to apply the pooled results to an uncomplicated extra-articular distal tibial fracture. A prospective evaluation taking into account early recovery, union, alignment, functional scoring, and procedure-specific complications is clinically useful. The present study thus sought to compare the functional outcome at 12 months of IMN with that of minimally invasive locking plate fixation (LPF) of extra-articular distal tibial fractures, hypothesizing that IMN would allow for earlier rehabilitation, whereas LPF would allow for more accurate radiographic alignment.

Materials and Methods

Study design and setting: This was a prospective comparative cohort study carried out in the Department of Orthopaedics of a tertiary care teaching hospital. Consecutive patients who presented to the hospital with a fractured distal tibia were recruited and followed for 12 months. The operating trauma unit determined the treatment based on the fracture morphology, length of the distal fragment, soft-tissue condition, fibular injury, and patient preference. Allocation was not random, so baseline variables were recorded a priori to evaluate comparability between cohorts.

Sample size: 104 patients were used, 52 in each treatment group, as an illustration. The target was to detect a difference of about 3 weeks in the mean radiographic union time, with a standard deviation of 5 weeks, two-sided alpha of 0.05, 80% power and allowing for attrition. The final analytic cohort was created to include all 104 patients with complete 12-month outcome data.

Inclusion criteria: Adults aged 18–70 years with a displaced, extra-articular distal tibial fracture with the main fracture line within about 8 cm from the tibial plafond and the fracture was suitable for either IMN or locking plate fixation. Distal-third shaft fractures without articular extension and AO/OTA type 43-A fractures were included. Exclusion criteria were intra-articular pilon fractures, Gustilo-Anderson grade II or III open injuries, pathological fractures, active local infection, major neurovascular injury requiring reconstruction, previous ipsilateral ankle or tibial surgery, established peripheral neuropathy, and polytrauma that prevented a standardized weight-bearing protocol.

Operative technique: IMN group patients had closed or limited-open reduction and reamed intramedullary nailing. A modern tibial nail with multiple distal interlocking options was used. When necessary to keep the alignment, poller or blocking screws, temporary percutaneous reduction clamps, and fibular fixation were used. When anatomy allowed, at least two distal locking screws were placed. In the LPF group, the fracture was indirectly reduced and stabilized with a precontoured medial distal tibial locking compression plate with minimal incisions. The construct was applied in the manner of bridge-plating, including restoration of length, rotation and mechanical axis. Selective fibular fixation was performed in either group when it aided in restoring length or ankle mortise stability.

Postoperative care and follow-up: Postoperatively, standard antibiotic and thromboembolism prophylaxis was given as per institutional protocol. Ankle/knee range of motion exercises were started as tolerated. Early clinical assessment allowed for the introduction of protected partial weight bearing after fixation stability and soft-tissue condition allowed, and progressive loading was based on callus formation and pain. Clinical and radiographic examinations were planned at 2 weeks, 6 weeks, 3 months, 6 months and 12 months.

The primary clinical outcomes were time to radiographic union and AOFAS ankle-hindfoot score at 12 months. Progressive weight bearing with bridging callus across at least three of four cortices on orthogonal radiographs was considered to be union. Delayed union was considered to be no satisfactory progression by 24 weeks and nonunion was considered to be failure of union that needed further intervention. Secondary measures included operative time, estimated blood loss, hospital admission, time to partial and full weight bearing,

serial AOFAS scores, infection, implant irritation, anterior knee pain, ankle stiffness, reoperation, and malalignment. Postoperative and follow-up radiographs were used to measure coronal and sagittal angulation, and malalignment was defined as more than 5 degrees in either plane.

Data analysis: Data analysis was done using statistical software similar to SPSS version 29.0.

Results

A total of 104 patients were included, with 52 treated using intramedullary nailing and 52 using minimally invasive locking plate fixation. The two cohorts were comparable with respect to age, sex, injury mechanism, fracture subtype, associated fibular fracture, and fracture distance from the plafond (Table 1). No baseline variable demonstrated a statistically significant between-group difference.

The IMN group had a shorter mean operative duration and lower estimated blood loss. Patients treated with IMN also progressed to partial and full weight bearing earlier. Mean union time was 18.4±4.1 weeks after IMN and 20.1±4.7 weeks after LPF (p=0.049). Early function favored IMN: the 3-month AOFAS score was 71.4±8.8 compared with 67.2±9.5 after LPF (p=0.021). The difference narrowed by 6 months and was no longer evident at 12 months, when both groups had mean AOFAS scores close to 90 (Table 2). Radiographically, the LPF cohort demonstrated slightly lower residual coronal and sagittal angulation. Malalignment greater than 5 degrees occurred in 5 patients (9.6%) after IMN and 2 (3.8%) after LPF, although this categorical difference did not reach statistical significance. Superficial wound infection was numerically more common after LPF, while anterior knee pain was significantly more frequent after IMN. Implant irritation showed the opposite pattern and was more common with the subcutaneous plate. Rates of delayed union, nonunion, deep infection, ankle stiffness, and reoperation were low and comparable (Table 3).

Discussion

The main result of this prospective cohort study is that IMN and locking plate fixation had similar functional results at 12 months, but did so via different early recovery and complication pathways. IMN was linked to reduced surgery time, blood loss, and time to weight bearing, as well as a small reduction in time to union. LPF also more accurately corrected mean coronal and sagittal alignment and did not impose the clinically significant burden of nail-related anterior knee pain. The results of this study are consistent with a patient-specific rather than technique-specific approach for extra-articular distal tibial fractures.

Table 1: Baseline demographic and fracture characteristics

Variable	IMN (n=52)	LPF (n=52)	p value
Age, years	42.8±12.7	44.1±11.9	0.592
Male sex, n (%)	36 (69.2)	34 (65.4)	0.680
High-energy mechanism, n (%)	31 (59.6)	29 (55.8)	0.691
AO/OTA 43-A1, n (%)	19 (36.5)	17 (32.7)	0.910*
AO/OTA 43-A2, n (%)	21 (40.4)	23 (44.2)	—
AO/OTA 43-A3, n (%)	12 (23.1)	12 (23.1)	—
Associated fibular fracture, n (%)	40 (76.9)	42 (80.8)	0.628
Fracture distance from plafond, cm	5.2±1.4	5.1±1.3	0.707

Values are mean±SD or n (%). *Overall comparison across AO/OTA subtypes. IMN, intramedullary nailing; LPF, locking plate fixation.

Table 2: Operative, union, rehabilitation, and functional outcomes

Outcome	IMN (n=52)	LPF (n=52)	p value
Operative time, min	78.6±14.2	94.8±18.5	<0.001
Estimated blood loss, Ml	96±38	128±52	<0.001
Hospital stay, days	5.8±2.1	6.6±2.4	0.073
Partial weight bearing, weeks	5.2±1.4	6.0±1.6	0.008
Full weight bearing, weeks	11.8±2.6	13.1±3.0	0.020
Radiographic union, weeks	18.4±4.1	20.1±4.7	0.049
AOFAS score at 3 months	71.4±8.8	67.2±9.5	0.021
AOFAS score at 6 months	83.1±7.4	81.0±7.8	0.162
AOFAS score at 12 months	89.5±6.6	90.1±6.2	0.633

AOFAS, American Orthopaedic Foot and Ankle Society ankle-hindfoot score. Higher scores indicate better function.

Table 3: Radiological alignment and complications

Outcome	IMN (n=52)	LPF (n=52)	p value
Mean coronal angulation, degrees	2.8±2.0	1.9±1.5	0.011
Mean sagittal angulation, degrees	2.6±1.8	1.8±1.4	0.014
Malalignment >5 degrees, n (%)	5 (9.6)	2 (3.8)	0.240
Superficial wound infection, n (%)	2 (3.8)	6 (11.5)	0.140
Deep infection, n (%)	1 (1.9)	1 (1.9)	1.000
Delayed union, n (%)	4 (7.7)	5 (9.6)	0.727
Nonunion, n (%)	1 (1.9)	2 (3.8)	1.000
Anterior knee pain, n (%)	9 (17.3)	1 (1.9)	0.008
Implant irritation, n (%)	2 (3.8)	7 (13.5)	0.080
Ankle stiffness, n (%)	3 (5.8)	6 (11.5)	0.294
Reoperation, n (%)	5 (9.6)	6 (11.5)	0.750

Categorical comparisons used chi-square or Fisher exact testing as appropriate.

The early functional benefit that is seen following IMN is biologically and mechanically sound. A load sharing nail is located in the center of the fracture site, usually does not need as much exposure to the fracture site, and allows for a construct that can withstand progressive axial loading relatively early. Barcak and Collinge reported similar eventual healing and function with both the minimally invasive plating and nailing techniques, with differences more evident in implant-related secondary procedures than in final function [8]. The current trend is in line with that idea: the distinction between techniques was greatest in the first few months, not at the 12-month mark.

The distal metaphyseal canal requires special consideration as it has less intrinsic control of the nail. In our simulated cohort, we found a small but statistically significant improvement in mean angular alignment for LPF, but no significant difference in the percentage of patients with an angle greater than 5 degrees. Liu et al. conducted a systematic review that showed that minimally invasive plating decreased the risk of malunion, and intramedullary nailing decreased the wound complications [9]. Hu et al. also concluded in their meta-analysis of randomized trials that there is a balance between alignment control and soft-tissue complications [10]. New methods like semi-extended positioning, temporary percutaneous clamps, fibular restoration, multiplanar distal locking, and blocking screws can minimize the historical malalignment risk associated with distal tibial nailing, but careful intraoperative imaging is still required.

The union findings also are consistent with more recent pooled evidence. Li et al. reviewed 20 randomized controlled trials and found that IMN resulted in shorter operative time, union time, and weight-bearing time, as well as fewer wound infections, but higher risks of malunion and anterior knee pain [11]. The uniformity of these analyses indicates that the disparities among methods are not so much related to the probability of union as to the pathway to union and the kind of morbidity experienced.

Wound complications are important especially in the distal tibia as the medial surface is subcutaneous and swelling is common. The difference in superficial infection between the two cohorts was not statistically significant, but the higher rate in the present cohort is clinically plausible. Although these techniques minimize this risk, incision placement, timing of surgery, soft-tissue handling and avoiding excessive plate prominence are still key. On the other hand, the high incidence of anterior knee pain following IMN is a crucial counseling point, particularly for those who kneel in their job or lifestyle. Some patients will still experience symptoms even if the entry point technique and the prominence of the nails are technically satisfactory.

This is also important because there is no meaningful difference between the AOFAS scores over the 12-month period. A fixation strategy that allows for earlier recovery may eventually merge with the other strategy at the end of the union and rehabilitation process. This underscores the importance of using more than one late functional score to define treatment success. The lower soft tissue burden in the distal tibia and earlier loading potential of IMN may be the deciding factor for a patient with poor soft tissue integrity. A locking plate may be better for a very short distal segment, a fracture that is likely to deform, or a patient with knee symptoms that would be problematic. Other factors such as associated fibular fractures, bone quality, fracture morphology, and surgeon experience should also play a role in the selection.

This study model has some limitations which need to be recognized when applying it to a manuscript. The allocation of treatment was not random, and even if baseline variables were balanced, there would still be residual selection bias. The sample size was sufficient for common continuous outcomes but not for uncommon events like deep

infection and nonunion. There are ceiling and measurement limitations with AOFAS scoring and patient-reported instruments like the Disability Rating Index or Olerud-Molander Ankle Score may enhance future studies. Routine use of CT to evaluate rotational alignment was not used, and 12 months may not be long enough to detect late ankle symptoms or implant removal. Most importantly, the numbers in this draft are not patient numbers, but are illustrative and should be replaced with actual study numbers before academic use.

Future prospective studies should further stratify fracture morphology, standardise fibular fixation and weight bearing protocols and include patient-reported outcomes, objective alignment measures, cost and return to work times. Distal tibial nails and low-profile locking plates are still evolving, and it is more feasible to reduce technique-specific complications than to find one superior implant.

Conclusion

Intramedullary nailing and minimally invasive locking plate fixation both achieved high union rates and comparable 12-month functional outcomes in extra-articular distal tibial fractures. IMN showed advantages in operative efficiency, early weight bearing, and union time, whereas LPF provided better angular alignment and substantially less anterior knee pain. Fixation should therefore be individualized according to fracture geometry, soft-tissue status, alignment risk, rehabilitation needs, and patient preference.

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