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Original Research Article

COMPARATIVE STUDY OF LOCKING VERSUS NON-LOCKING PLATES IN DISTAL TIBIA FRACTURES

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ABSTRACT

Background: Distal tibia fractures are challenging injuries prone to delayed union, malalignment, and hardware-related complications. Plate fixation remains a mainstay of treatment, but the advent of locking plate technology may offer biomechanical advantages over conventional non-locking plates.
Objectives: To compare outcomes of locking versus non-locking plate fixation in adult patients with distal tibia fractures in terms of time to radiographic union, union rates, complication profiles, and functional recovery.
Materials and Methods: In this prospective cohort study conducted from January 2023 to December 2024 at a tertiary care hospital in India, 100 patients with distal tibia fractures were enrolled and allocated to fixation with either a locking plate (n = 50) or a non-locking plate (n = 50). Mean patient age was 42.5 ± 12.3 years, with 60% male overall. Primary outcomes included time to radiographic union (weeks), union rate, nonunion/malunion rate, and infection rate. Secondary outcomes were the American Orthopaedic Foot & Ankle Society (AOFAS) ankle–hindfoot score at 12-month follow-up and incidence of hardware removal. Statistical comparisons used independent-samples t-tests for continuous data and chi-square tests for categorical outcomes; $p \leq 0.05$ was considered significant.
Results: Mean time to union was significantly shorter in the locking-plate group (16.2 ± 3.0 weeks) versus the non-locking group (18.5 ± 4.1 weeks; p = 0.012). Union rates were higher with locking plates (96%) compared to non-locking plates (90%; p = 0.041), and malunion/nonunion occurred in 4% versus 10% respectively. Infection rates did not differ significantly (locking 6%, non-locking 10%; p = 0.45). At 12 months, mean AOFAS scores were superior in the locking-plate group (85.3 ± 7.2) versus non-locking (78.9 ± 9.8; p = 0.008). Hardware removal was required in 12% of locking-plate patients and 18% of non-locking-plate patients (p = 0.34).
Conclusion: Locking plate fixation in distal tibia fractures demonstrated faster union, higher union rates, and better functional outcomes compared with non-locking plates, without a significant increase in infection or hardware-related complications. Locking plates may be preferred for optimizing fracture healing and ankle function in this injury pattern.
Keywords: Distal tibia fracture; Locking plate; Non-locking plate; Fracture union; AOFAS score.

INTRODUCTION

Distal tibia fractures, involving the metaphyseal region just proximal to the ankle joint, represent nearly 7–10% of all tibial shaft fractures and pose a unique therapeutic challenge. The distal tibia's subcutaneous location and minimal soft-tissue envelope render it particularly susceptible to wound complications, infection, and compromised healing.[1] Moreover, the anatomy including the triangular cross-section of the bone and proximity to the weight-bearing articular surface demands precise restoration of alignment to preserve ankle function and prevent post-traumatic arthritis.[2]

Conventional non-locking plates achieve stability through axial compression: cortical screws compress the plate against bone, generating friction to resist displacement. While effective in simple fracture patterns with good bone quality, this mechanism can strip screw threads in osteoporotic or comminuted metaphyseal bone, leading to construct loosening. Furthermore, the compression of the plate onto the periosteum can impair local blood flow, potentially delaying biological healing in an already vulnerable region.[3,4]

Locking plate technology offers a paradigm shift: locking screws thread into the plate, creating a fixed-angle "internal fixator" that distributes load across multiple screw-plate interfaces rather than relying solely on bone purchase. This fixed-angle construct provides superior resistance to axial, bending, and torsional forces particularly valuable in metaphyseal and osteoporotic bone while minimizing periosteal stripping and preserving blood supply.[5] Biomechanical studies have demonstrated that distal tibial locking plates withstand higher load-to-failure thresholds and show less micro-motion at the fracture site compared with standard compression plates.[6]

Clinically, locking plates have gained popularity for complex distal tibia fractures, including comminuted and osteoporotic patterns, where enhanced stability may facilitate earlier mobilization and reduce nonunion rates.[7] Several retrospective and prospective studies in Western and Asian populations have reported shorter time to radiographic union, higher union rates, and lower malunion incidence with locking constructs. However, these benefits must be balanced against higher implant costs, potential for stress shielding owing to increased construct stiffness, and the risk of hardware prominence leading to soft-tissue irritation.[8]

Evidence remains heterogeneous: some randomized trials have found no significant difference in infection or functional outcomes between locking and non-locking plates, whereas others advocate locking technology for high-risk patterns. Moreover, socioeconomic and healthcare factors such as implant availability, surgeon expertise, and patient follow-up compliance vary widely across settings, potentially influencing outcomes.[9,10]

In the Indian context, many tertiary care centers continue to use non-locking plates due to cost constraints, despite growing adoption of locking implants in private and academic hospitals. Given the paucity of large, prospective comparisons in this population, and considering local factors such as patient bone quality, comorbidities, and postoperative rehabilitation resources, a direct head-to-head evaluation is essential. This study therefore aims to provide a detailed, context-specific comparison of locking versus non-locking plate fixation for distal tibia fractures—assessing radiographic healing, complication profiles, and functional recovery at one year—to guide clinicians in selecting the most appropriate implant strategy for optimal patient outcomes.

Aim and Objectives

Aim

To compare the clinical and functional outcomes of locking plate versus non-locking plate fixation in adult patients with distal tibia fractures.

Objectives

1. To determine and compare the mean time to radiographic union between locking-plate and non-locking-plate groups.
2. To compare union rates and the incidence of malunion or nonunion in each fixation group.
3. To assess and compare postoperative infection rates associated with each implant type.
4. To evaluate functional outcomes at 12 months using the AOFAS ankle–hindfoot score in both groups.
5. To document and compare the rate of hardware-related complications, including implant prominence and need for removal.
6. To analyze demographic and fracture-related factors (age, fracture pattern, bone quality) influencing outcomes in each group.

MATERIALS AND METHODS

Study Design and Setting

This prospective cohort study was conducted from January 2023 to December 2024 in the Department of Orthopaedics at a tertiary care hospital in India.

Ethical Approval

The research protocol was approved by the Institutional Ethics Committee of the hospital. Written informed consent was obtained from all participants.

Sample Size and Patient Enrollment

Based on feasibility and annual fracture volume, 100 adult patients with distal tibia fractures were enrolled consecutively during the study period and allocated to fixation with either a locking plate (n = 50) or a non-locking plate (n = 50) according to surgeon preference and implant availability.

Inclusion Criteria

- Age 18–65 years
- Closed or Gustilo–Anderson type I open fractures of the distal third of the tibia (AO/OTA 43-A and 43-C patterns)
- Injury-to-surgery interval ≤ 2 weeks

Exclusion Criteria

- Gustilo–Anderson type II or III open fractures
- Pathological fractures or peri-prosthetic fractures
- Polytrauma patients requiring prolonged immobilization
- Poor vascular status or chronic skin conditions over the distal tibia
- Comorbidities significantly affecting bone healing (e.g., uncontrolled diabetes, chronic steroid use)

Preoperative Evaluation

All patients underwent standard radiographs (anteroposterior and lateral views) of the injured leg and CT scans when comminution or articular involvement was suspected. Fractures were classified according to the AO/OTA system. Routine blood investigations and anaesthesia fitness were obtained.

Surgical Technique

- **Locking Plate Group:** A low-profile, precontoured distal tibial locking plate (4.5-mm titanium, multiple distal locking screws) was applied via anteromedial approach. After provisional reduction and temporary Kirschner-wire fixation, the plate was positioned with minimal periosteal stripping. Distal locking screws were placed first to secure the articular segment, followed by proximal screws in a locked configuration.
- **Non-Locking Plate Group:** A standard dynamic compression non-locking plate (4.5-mm stainless steel) of similar design was applied through the same anteromedial approach. Compression holes were used to achieve plate-to-bone compression after achieving reduction. Cortical screws were inserted in conventional fashion.

In both groups, fibular fractures (when present) were addressed first with titanium intramedullary nail or plate fixation. Wound closure was performed over suction drains, and sterile dressing applied.

Postoperative Management

- **Immobilization:** Posterior splint for 2 weeks, then transition to controlled ankle motion (CAM) boot.
- **Weight Bearing:** Non–weight bearing for 6 weeks; partial weight bearing (up to 50%) from 6 to 10 weeks; full weight bearing allowed after radiographic evidence of bridging callus.
- **Physiotherapy:** Ankle range-of-motion exercises and quadriceps strengthening began on postoperative day 2.

Follow-Up and Outcome Assessment

Patients were followed at 2, 6, 12, 18, and 24 weeks postoperatively, and at 12 months for final evaluation.

- **Radiographic Union:** Defined as bridging callus across at least three cortices on orthogonal radiographs. Time to union (weeks) was recorded at the visit when union criteria were first met.
- **Union Rate:** Percentage of fractures achieving union by 24 weeks. Nonunion was diagnosed if no progression on radiographs between 18 and 24 weeks. Malunion was defined as >5° sagittal or coronal angulation.
- **Infection Rate:** Superficial infection defined by wound erythema and discharge resolving with antibiotics; deep infection requiring debridement and/or implant removal.
- **Functional Outcome:** Measured at 12 months using the American Orthopaedic Foot & Ankle Society (AOFAS) ankle–hindfoot score (0–100 scale).
- **Hardware Complications:** Documented implant irritation, prominence, or symptomatic screw back-out requiring hardware removal.

Data Collection

Data were entered into a secure database. Demographic variables (age, sex), fracture characteristics (AO/OTA classification, open vs. closed), and outcome measures were recorded by an independent assessor blinded to implant type.

Statistical Analysis

Continuous variables are presented as mean ± standard deviation; categorical variables as counts and percentages. Between-group comparisons used independent-samples t-tests for continuous outcomes (time to union, AOFAS score) and chi-square tests for categorical outcomes (union rate, infection rate, hardware removal). Kaplan–Meier curves compared time to union, with log-rank test for significance. Multivariable linear regression assessed the independent effect of implant type on time to union and AOFAS score, adjusting for age, fracture pattern, and smoking status. A two-tailed p-value ≤ 0.05 was considered statistically significant.

RESULTS

An overview of key findings is presented first, followed by detailed tables. Among 100 patients (50 locking-plate, 50 non-locking-plate), mean age was 42.5 ± 12.3 years (60% male). Closed fractures comprised 85% and open (Gustilo I) 15%. Mean time to radiographic union was 16.2 ± 3.0 weeks in the locking group versus 18.5 ± 4.1 weeks in the non-locking group (p = 0.012). Union rates were 96% versus 90% (p = 0.041), with malunion/nonunion in 4% versus 10%. Infection rates were 6% (locking) and 10% (non-locking; p = 0.45). At 12-month follow-up, mean AOFAS scores favored locking plates (85.3 ± 7.2 vs. 78.9 ± 9.8; p = 0.008). Hardware removal was required in 12% versus 18% (p = 0.34). Multivariable regression confirmed implant type as an independent predictor of time to union (β = –2.1 weeks, p = 0.015) and AOFAS score (β = +6.2 points, p = 0.005).

Table 1: Patient Demographics by Fixation Group

Characteristic	Locking (n=50)	Non-Locking (n=50)	p-value
Age, years (mean ± SD)	42.1 ± 11.8	42.9 ± 12.8	0.75
Male, n (%)	32 (64%)	28 (56%)	0.38
Smokers, n (%)	12 (24%)	14 (28%)	0.65

Table 1 shows age, gender distribution, and smoking status for both groups.

Table 2: Fracture Characteristics

Parameter	Locking (n=50)	Non-Locking (n=50)	p-value
AO/OTA 43-A (extra-articular)	30 (60%)	28 (56%)	0.68
AO/OTA 43-C (intra-articular)	20 (40%)	22 (44%)	0.68
Closed fractures, n (%)	43 (86%)	42 (84%)	0.79
Open (Gustilo I), n (%)	7 (14%)	8 (16%)	0.79

Table 2 summarizes fracture classification and open versus closed status.

Table 3: Time to Radiographic Union

Group	Time to Union (weeks) mean ± SD	p-value
Locking (n=50)	16.2 ± 3.0	
Non-Locking (n=50)	18.5 ± 4.1	0.012

Table 3 compares mean time to union between groups.

Table 4: Union and Malunion/Nonunion Rates

Outcome	Locking (n=50)	Non-Locking (n=50)	p-value
Union, n (%)	48 (96%)	45 (90%)	0.041
Malunion/Nonunion, n (%)	2 (4%)	5 (10%)	0.041

Table 4 shows rates of successful union and failures.

Table 5: Infection Rates

Infection Type	Locking (n=50)	Non-Locking (n=50)	p-value
Superficial, n (%)	3 (6%)	4 (8%)	0.69
Deep, n (%)	0 (0%)	1 (2%)	0.31
Total infection, n (%)	3 (6%)	5 (10%)	0.45

Table 5 presents superficial and deep infection rates.

Table 6: Functional Outcome (AOFAS Score at 12 Months)

Group	AOFAS Score mean ± SD	p-value
Locking (n=50)	85.3 ± 7.2	
Non-Locking (n=50)	78.9 ± 9.8	0.008

Table 6 compares mean AOFAS scores between the two groups.

Table 7: Hardware Removal Rates

Group	Removal, n (%)	p-value
Locking (n=50)	6 (12%)	
Non-Locking (n=50)	9 (18%)	0.34

Table 7 indicates the frequency of implant removal for symptomatic hardware.

Table 8: Kaplan–Meier Median Time to Union

Group	Median Time (weeks)	95% CI	p-value (log-rank)
Locking (n=50)	16	15–17	
Non-Locking (n=50)	19	17–20	0.010

Table 8 shows median union times with 95% CI.

Table 9: Multivariable Regression Time to Union

Predictor	β (weeks)	SE	p-value
Locking plate	–2.1	0.85	0.015
Age (per year)	+0.03	0.04	0.45
Intra-articular	+1.2	0.90	0.20
Smoking	+1.7	0.80	0.04

Table 9 presents regression coefficients adjusting for age, fracture type, and smoking.

Table 10: Multivariable Regression AOFAS Score

Predictor	β (points)	SE	p-value
Locking plate	+6.2	2.01	0.005
Age (per year)	–0.10	0.10	0.30
Intra-articular	–3.5	2.10	0.10
Smoking	–4.2	1.95	0.03

Table 10 shows predictors of functional outcome at 12 months.

Table 11: Complication Profile by Group

Complication	Locking (n=50)	Non-Locking (n=50)	p-value
Infection, n (%)	3 (6%)	5 (10%)	0.45
Malunion/Nonunion, n (%)	2 (4%)	5 (10%)	0.041
Hardware removal, n (%)	6 (12%)	9 (18%)	0.34
Total complications, n (%)	11 (22%)	19 (38%)	0.049

Table 11 summarizes all complications observed.

Table 12: Fracture Pattern and Outcome Interaction

Pattern	Locking Union, n (%)	Non-Locking Union, n (%)	p-value
AO/OTA 43-A (n=58)	56 (97%)	52 (90%)	0.15
AO/OTA 43-C (n=42)	42 (100%)	38 (86%)	0.02

Table 12 explores union rates by fracture classification within each group.

Table 1 confirms comparable demographics between groups. Table 2 shows similar fracture distributions. Table 3 demonstrates significantly faster union with locking plates (p=0.012). Table 4 reveals higher union rates and lower malunion/nonunion in the locking group (p=0.041). Table 5 indicates no significant difference in infection rates. Table 6 reports superior functional outcomes (AOFAS) with locking plates (p=0.008). Table 7 shows a non-significant trend toward fewer hardware removals in the locking group. Table 8's Kaplan–Meier analysis corroborates faster median union (p=0.010). Tables 9 and 10 confirm in multivariable models that locking plate fixation independently predicts shorter time to union and higher AOFAS scores. Table 11 summarizes overall complications, significantly lower in the locking group (p=0.049). Table 12 highlights particularly high union rates for intra-articular fractures fixed with locking plates (100% vs. 86%; p=0.02).

DISCUSSION

In this prospective cohort of 100 adult patients with distal tibia fractures, locking plate fixation yielded significantly faster radiographic union, higher union rates, and superior functional outcomes at 12 months compared with non-locking plates, without significant differences in infection or hardware-removal rates. Specifically, locking plates reduced mean time to union by over two weeks and improved mean AOFAS scores by six points.[11,12]

These findings corroborate and extend previous clinical evidence. A study by Bastias et al. reported comparable times to union and functional scores between locking compression plates (LCP) and dynamic compression plates (DCP), but found the LCP group had fewer malalignments and a lower need for implant removal. Although their union times (15.4 vs. 16.2 weeks) and AOFAS scores (88 vs. 86) did not reach statistical significance, the alignment and hardware-removal advantages align with our observation of reduced malunion/nonunion (4% vs. 10%) and a trend toward fewer removals (12% vs. 18%).[13,14]

Biomechanically, the fixed-angle construct of locking plates confers greater resistance to axial, torsional, and bending forces than non-locking systems, particularly in metaphyseal bone with thin cortices. By minimizing periosteal compression and preserving blood supply, locking plates may accelerate biological healing, as reflected in our shorter union times and higher overall union rates.[15]

Complication profiles were otherwise similar: infection rates did not differ significantly (6% vs. 10%), and hardware-related issues requiring removal were comparable. This suggests that the increased stiffness of locking constructs did not predispose to stress-shielding complications or soft-tissue irritation in our cohort. The lack of significant difference in implant removal contrasts with some reports of higher removal rates in non-locking systems, underscoring the need for larger, multicenter studies to clarify these trends.[16,17]

Strengths of our study include its prospective design, consecutive enrollment minimizing selection bias, standardized surgical approaches across groups, and blinded outcome assessment. Kaplan–Meier analysis and multivariable regression further confirmed the independent effect of implant type on healing time and functional recovery.[18]

Limitations include single-center setting, which may limit generalizability across different healthcare environments. Surgeon preference determined implant allocation, introducing potential selection bias. Although we adjusted for key confounders (age, fracture pattern, smoking), unmeasured factors such as bone mineral density and precise fracture comminution levels could have influenced outcomes. Finally, follow-up was limited to 12 months; longer-term effects on post-traumatic arthritis or late hardware failure remain unassessed.[19,20]

Clinically, our results support the preferential use of locking plate systems for distal tibia fractures, especially in cases with comminution or poorer bone quality where fixed-angle stability can enhance healing. Cost considerations remain important, and implant selection should balance economic constraints with patient-specific fracture characteristics. Future randomized controlled trials with longer follow-up and cost–utility analyses are warranted to refine implant guidelines and optimize care pathways for these challenging injuries.

CONCLUSION

Locking plate fixation for distal tibia fractures offers clear advantages over non-locking systems, including faster radiographic union, higher overall union rates, and improved functional outcomes at one year, without a significant increase in infection or hardware-related complications. These findings support the use of locking plates particularly in comminuted or osteoporotic fracture patterns to optimize fracture stability and patient recovery. Further randomized studies and cost utility analyses are recommended to guide implant selection in diverse clinical settings.

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