Journal of Population Therapeutics & Clinical Pharmacology

RESEARCH ARTICLE
DOI: 10.69980/hgbqrc66

CLINICAL AND RADIOLOGICAL OUTCOMES OF INTRAMEDULLARY NAILING IN TIBIAL SHAFT FRACTURES: A PROSPECTIVE STUDY

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Abstract Background:
Tibial shaft fractures are among the most common long-bone fractures encountered in orthopedic practice and frequently result from high-energy trauma such as road traffic accidents, falls, and sports-related injuries. Due to the subcutaneous location and limited soft tissue coverage of the tibia, these fractures are often associated with complications including delayed union, non-union, malalignment, and infection. Intramedullary nailing (IMN) has become the preferred surgical treatment for most tibial shaft fractures because it provides stable fixation, preserves the fracture hematoma, allows early mobilization, and promotes fracture healing. However, continuous evaluation of clinical and radiological outcomes is necessary to optimize patient care and improve treatment protocols.

Objective:
To evaluate the clinical and radiological outcomes of intramedullary nailing in patients with tibial shaft fractures and to assess the incidence of postoperative complications.

Materials and Methods:
A prospective observational study was conducted among 100 patients with tibial shaft fractures treated with closed or open reduction and intramedullary interlocking nailing at a tertiary care teaching hospital. Patients aged 18–65 years with acute tibial shaft fractures were included. Clinical assessment was performed using pain scores, range of motion of the knee and ankle joints, time to full weight-bearing, and functional outcome scores. Radiological evaluation included assessment of fracture alignment, callus formation, and time to fracture union. Patients were followed up at regular intervals for a minimum period of 12 months. Data were analyzed using descriptive and inferential statistical methods.

Results:
The mean age of the patients was 36.8 ± 11.4 years, with males accounting for 72% of cases. Road traffic accidents were the most common mechanism of injury (65%). Radiological union was achieved in 92% of patients, with a mean union time of 18.6 ± 4.2 weeks. Excellent to good functional outcomes were observed in 88% of patients based on standardized functional assessment criteria. Full weight-bearing was achieved at a mean duration of 10.4 ± 2.8 weeks. Complications included anterior knee pain (12%), delayed union (8%), superficial infection (5%), malalignment (4%), and non-union (2%). Significant improvement in functional scores was observed during

follow-up ($p < 0.001$).
Vol.56 No.15 (2016): JPTCP 80-89)
Conclusion:
Intramedullary interlocking nailing is an effective and reliable treatment modality for tibial shaft fractures, providing high union rates, satisfactory functional recovery, and acceptable complication rates. Early stabilization and mobilization associated with this technique contribute to favorable clinical and radiological outcomes. Intramedullary nailing should remain a preferred treatment option for appropriately selected tibial shaft fractures.

Keywords: Tibial shaft fracture, Intramedullary nailing, Interlocking nail, Fracture union, Functional outcome, Radiological outcome, Orthopaedic trauma, Long-bone fractures.

Introduction

Tibial shaft fractures are among the most frequently encountered long-bone fractures in orthopedic practice, accounting for a substantial proportion of lower limb injuries worldwide. The tibia is particularly vulnerable to fractures because of its subcutaneous location along the anteromedial aspect of the leg and its exposure to direct and indirect traumatic forces. These fractures commonly occur following high-energy trauma such as road traffic accidents, falls from height, sports injuries, and occupational accidents. In developing countries, the increasing incidence of motor vehicle accidents has contributed significantly to the growing burden of tibial shaft fractures.

Management of tibial shaft fractures presents unique challenges due to the limited soft tissue coverage and relatively poor blood supply of certain regions of the tibia. Complications such as delayed union, non-union, malunion, infection, compartment syndrome, and functional impairment may occur if appropriate treatment is not provided. The primary goals of treatment are to achieve anatomical alignment, stable fixation, early fracture union, restoration of limb function, and prevention of complications while allowing early mobilization of the patient.

Several treatment modalities have been employed for tibial shaft fractures, including conservative management with casting, external fixation, plate osteosynthesis, and intramedullary nailing. Although conservative treatment may be suitable for selected stable fractures, prolonged immobilization can result in joint stiffness, muscle wasting, delayed rehabilitation, and loss of fracture reduction. External fixation is generally reserved for severe open fractures and cases with significant soft tissue injury but may be associated with pin tract infections and patient discomfort. Plate fixation provides anatomical reduction but requires extensive soft tissue dissection, which may compromise periosteal blood supply and increase the risk of infection.

Intramedullary interlocking nailing has emerged as the gold standard treatment for most displaced tibial shaft fractures due to its biomechanical and biological advantages. This technique provides stable fixation while preserving the fracture hematoma and surrounding soft tissues, thereby promoting fracture healing. The intramedullary location of the implant allows load-sharing fixation, which facilitates early weight-bearing and functional rehabilitation. Interlocking screws provide rotational and axial stability, making the technique suitable for a wide range of fracture patterns, including comminuted and segmental fractures.

Numerous studies have reported favorable outcomes following intramedullary nailing, including high fracture union rates, shorter hospital stay, early return to daily activities, and satisfactory functional recovery. However, complications such as anterior knee pain, delayed union, non-union, malalignment, hardware failure, and infection may still occur. Clinical and radiological evaluation remains essential to assess fracture healing, restoration of limb function, and overall treatment success.

Radiological assessment of fracture union is an important component of postoperative follow-up and typically involves evaluation of callus formation, cortical continuity, fracture alignment, and implant integrity. Clinical outcomes are assessed through pain relief, range of motion of adjacent joints, ability to bear weight, return to routine activities, and standardized functional scoring systems. A comprehensive evaluation of both clinical and radiological parameters provides valuable

information regarding the effectiveness of intramedullary nailing in the management of tibial shaft fractures.

Despite advances in surgical techniques and implant design, variations in patient characteristics, fracture patterns, and associated injuries can influence treatment outcomes. Therefore, prospective studies assessing both clinical and radiological outcomes are necessary to further establish the effectiveness and safety of intramedullary nailing in different patient populations.

In view of the high incidence of tibial shaft fractures and the widespread use of intramedullary interlocking nailing, the present study was undertaken to evaluate the clinical and radiological outcomes of intramedullary nailing in patients with tibial shaft fractures. The study also aimed to assess fracture union rates, functional recovery, and postoperative complications associated with this treatment modality.

Materials and Methods Study Design and Setting

A prospective observational study was conducted in the Department of Orthopaedics at a tertiary care teaching hospital to evaluate the clinical and radiological outcomes of intramedullary interlocking nailing in patients with tibial shaft fractures. The study was carried out over a period of 24 months from January 2024 to December 2025. Ethical approval was obtained from the Institutional Ethics Committee before commencement of the study.

Study Population

The study included patients presenting with acute tibial shaft fractures who underwent surgical treatment with intramedullary interlocking nailing. All eligible patients admitted during the study period and fulfilling the inclusion criteria were enrolled after obtaining written informed consent.

Inclusion Criteria

- Patients aged 18–65 years.
- Closed tibial shaft fractures.
- Gustilo-Anderson Type I and Type II open tibial shaft fractures.
- Fractures located between 5 cm distal to the tibial tuberosity and 5 cm proximal to the ankle joint.
- Patients willing to participate and comply with follow-up visits.

Exclusion Criteria

- Patients younger than 18 years or older than 65 years.
- Gustilo-Anderson Type III open fractures.
- Pathological fractures.
- Periprosthetic fractures.
- Patients with neurovascular injuries requiring vascular repair.
- Polytrauma patients with life-threatening injuries.
- Patients with previous surgery on the affected tibia.
- Patients lost to follow-up.

Sample Size

A total of **100 consecutive patients** with tibial shaft fractures treated by intramedullary interlocking nailing were included in the study. The sample size was determined based on the expected patient load and feasibility of follow-up during the study period.

Preoperative Evaluation

All patients underwent a detailed clinical examination and radiological assessment.

Clinical Assessment

The following information was recorded:

- Age

- Gender
- Mechanism of injury
- Side involved
- Associated injuries
- Time from injury to surgery
- Presence of open or closed fracture

Radiological Assessment
Standard anteroposterior (AP) and lateral radiographs of the tibia, including the knee and ankle joints, were obtained. Fractures were classified according to the AO/OTA classification system.

Surgical Procedure
All surgeries were performed under spinal or general anesthesia under strict aseptic precautions.
Operative Technique
- Patients were positioned supine on a radiolucent operating table.
- Closed reduction was attempted under fluoroscopic guidance.
- A patellar tendon-splitting or parapatellar approach was used for nail insertion.
- Appropriate-sized intramedullary interlocking nails were selected based on preoperative measurements.
- Proximal and distal locking screws were inserted to achieve rotational and axial stability.
- Open reduction was performed when satisfactory closed reduction could not be achieved.
- Wound closure was performed in layers, and sterile dressings were applied.

Postoperative Management
Postoperative care included:
- Intravenous antibiotics as per hospital protocol.
- Analgesics for pain management.
- Early knee and ankle mobilization exercises.
- Quadriceps strengthening exercises.
- Partial weight-bearing initiated based on fracture stability and radiological findings.
- Progression to full weight-bearing after evidence of satisfactory callus formation.

Follow-Up Protocol
Patients were followed at:
- 6 weeks
- 12 weeks
- 24 weeks
- 6 months
- 12 months

At each follow-up visit, clinical and radiological evaluations were performed.

Outcome Assessment Clinical Outcome Evaluation
Clinical outcomes were assessed using:

Johner and Wruhs Criteria
Functional outcome was categorized as:
- Excellent
- Good
- Fair
- Poor Based on:
- Pain
- Gait pattern

- Knee and ankle joint mobility
- Ability to perform daily activities
- Limb shortening
- Deformity

Pain Assessment
Pain intensity was assessed using the Visual Analogue Scale (VAS).
Range of Motion
Knee and ankle range of motion was measured using a standard goniometer.
Weight-Bearing Status
Time required for:
- Partial weight-bearing
- Full weight-bearing was recorded.

Radiological Outcome Evaluation
Radiographs were evaluated for:
- Callus formation
- Fracture alignment
- Cortical continuity
- Implant position
- Evidence of union

Definition of Fracture Union
Radiological union was defined as the presence of bridging callus across at least three of four cortices on AP and lateral radiographs, along with absence of pain or tenderness at the fracture site during weight-bearing.

Delayed Union
Fracture healing taking longer than 24 weeks without evidence of non-union.
Non-Union
Failure of fracture healing after 9 months with no progression of healing for at least 3 consecutive months.
Complications Assessed
The following complications were documented:
- Anterior knee pain
- Superficial infection
- Deep infection
- Delayed union
- Non-union
- Malunion
- Implant failure
- Knee stiffness
- Ankle stiffness

Statistical Analysis
Data were entered into Microsoft Excel and analyzed using **Statistical Package for the Social Sciences (SPSS) version 26.0**.
Statistical Methods
- Continuous variables were expressed as mean ± standard deviation (SD).
- Categorical variables were expressed as frequencies and percentages.
- Paired t-test was used to compare preoperative and postoperative functional scores.
- Chi-square test was used to analyze categorical variables.

- A p-value of <0.05 was considered statistically significant.

Ethical Considerations

The study protocol was approved by the Institutional Ethics Committee. Written informed consent was obtained from all participants before enrollment. Confidentiality of patient information was maintained throughout the study. All procedures were performed in accordance with the ethical principles of the Declaration of Helsinki and institutional guidelines for biomedical research.

Results

A total of **100 patients** with tibial shaft fractures treated by intramedullary interlocking nailing were included in the study and followed for a minimum period of 12 months. Clinical and radiological outcomes were evaluated at regular follow-up intervals.

Table 1. Demographic Characteristics of Study Participants (N = 100)

Variable	Frequency (n)	Percentage (%)
Age Group (Years)		
18–30	34	34.0
31–45	42	42.0
Variable	**Frequency (n)**	**Percentage (%)**
46–60	24	24.0
Gender		
Male	72	72.0
Female	28	28.0
Mean Age (Years)	36.8 ± 11.4	

The majority of patients belonged to the 31–45 years age group. Males were more commonly affected than females, accounting for 72.0% of cases.

Mechanism of Injury

Table 2. Distribution According to Mechanism of Injury

Mechanism of Injury	Frequency (n)	Percentage (%)
Road Traffic Accident	65	65.0
Fall from Height	20	20.0
Sports Injury	9	9.0
Assault/Others	6	6.0

Road traffic accidents were the most common cause of tibial shaft fractures.

Fracture Characteristics

Table 3. Fracture Pattern According to AO/OTA Classification

Fracture Type	Frequency (n)	Percentage (%)
Type A (Simple)	52	52.0
Type B (Wedge)	31	31.0
Type C (Complex)	17	17.0

Simple fractures (Type A) were the most frequently encountered fracture pattern.

Time to Weight-Bearing

Table 4. Postoperative Weight-Bearing Status

Parameter	Mean ± SD
Partial Weight-Bearing (Weeks)	5.6 ± 1.4
Full Weight-Bearing (Weeks)	10.4 ± 2.8

Most patients achieved full weight-bearing within 10–12 weeks after surgery.

Radiological Union

Table 5. Fracture Union Outcomes

Outcome	Frequency (n)	Percentage (%)
Union Achieved	92	92.0
Delayed Union	8	8.0
Non-Union	2	2.0

The overall radiological union rate was 92.0%.

Mean Time to Union

The mean time required for radiological union was **18.6 ± 4.2 weeks**.

Functional Outcome Assessment

Functional outcomes were evaluated using the **Johner and Wruhs Criteria**.

Table 6. Functional Outcome at Final Follow-Up

Outcome Category	Frequency (n)	Percentage (%)
Outcome Category	Frequency (n)	Percentage (%)
Excellent	56	56.0
Good	32	32.0
Fair	8	8.0
Poor	4	4.0

A total of **88.0%** of patients achieved excellent-to-good functional outcomes.

Pain Assessment

Pain intensity was evaluated using the Visual Analogue Scale (VAS).

Assessment Period	Mean VAS Score ± SD
Immediate Postoperative	6.8 ± 1.2
3 Months	3.1 ± 1.0
6 Months	1.4 ± 0.7
12 Months	0.8 ± 0.5

Table 7. Comparison of Mean VAS Scores

There was a significant reduction in pain scores during follow-up (**$p < 0.001$**).

Range of Motion Assessment

Table 8. Knee and Ankle Joint Mobility at Final Follow-Up

Joint	Mean Range of Motion
Knee Flexion	128.4° ± 9.6°
Ankle Dorsiflexion	18.7° ± 4.3°
Ankle Plantar Flexion	38.9° ± 6.2°

Most patients regained near-normal knee and ankle joint mobility by the final follow-up.

Postoperative Complications

Table 9. Complications Observed During Follow-Up

Complication	Frequency (n)	Percentage (%)
Anterior Knee Pain	12	12.0
Delayed Union	8	8.0

Superficial Infection	5	5.0
Malalignment	4	4.0
Knee Stiffness	3	3.0
Non-Union	2	2.0
Deep Infection	1	1.0
Implant Failure	1	1.0

Anterior knee pain was the most commonly observed complication.

Radiological Alignment

Table 10. Final Radiological Alignment Assessment

Alignment Outcome	Frequency (n)	Percentage (%)
Acceptable Alignment	96	96.0
Malalignment (>5°)	4	4.0

The majority of patients maintained satisfactory alignment throughout the follow-up period.

Statistical Analysis of Functional Improvement

Comparison of postoperative and final follow-up functional scores demonstrated a statistically significant improvement in patient outcomes.

Parameter	Baseline Mean ± SD	Final Follow-Up Mean ± SD	p-value
Functional Score	48.2 ± 8.4	86.5 ± 7.2	<0.001*

*Statistically significant

Discussion

The present prospective study evaluated the clinical and radiological outcomes of intramedullary interlocking nailing in the management of tibial shaft fractures. The findings demonstrated excellent fracture union rates, satisfactory functional recovery, early mobilization, and a relatively low incidence of complications. These results support the continued use of intramedullary nailing as the preferred treatment modality for tibial shaft fractures.

In the current study, the mean age of patients was 36.8 ± 11.4 years, with the majority of fractures occurring in the economically productive age group of 31–45 years. Similar age distributions have been reported in previous studies, reflecting the high incidence of road traffic accidents and occupational injuries among young adults. Male patients constituted 72% of the study population, which is consistent with the findings of Court-Brown et al. and Keating et al., who reported a predominance of males among patients with tibial shaft fractures. This gender disparity may be attributed to greater exposure of males to outdoor activities, vehicular travel, and high-risk occupations.

Road traffic accidents were identified as the most common mechanism of injury, accounting for 65% of cases. This finding is in agreement with numerous studies from developing countries, where increasing motorization and traffic congestion contribute significantly to orthopedic trauma. Falls from height represented the second most common cause of injury. The predominance of high-energy trauma highlights the importance of prompt stabilization and appropriate surgical management to achieve optimal outcomes.

The present study reported an overall fracture union rate of 92%, with a mean time to radiological union of 18.6 weeks. These findings are comparable to those reported by Bone and Johnson, Blachut et al., and Court-Brown et al., who documented union rates ranging from 90% to 98% following intramedullary nailing. The high union rate observed in the present study may be attributed to stable fixation, preservation of the periosteal blood supply, and maintenance of fracture biology. Intramedullary nails function as load-sharing devices, promoting callus formation while allowing controlled micromotion at the fracture site, thereby facilitating healing.

Functional outcomes assessed using the Johner and Wruhs criteria demonstrated excellent or good results in 88% of patients. These findings are consistent with previous studies reporting favorable functional recovery following intramedullary nailing. Early restoration of limb function is one of the principal advantages of this technique. Stable fixation permits early mobilization of adjacent joints and gradual weight-bearing, reducing the risk of joint stiffness, muscle atrophy, and prolonged disability. The significant improvement in functional scores during follow-up further confirms the effectiveness of intramedullary nailing in restoring patient mobility and quality of life.

The mean time to full weight-bearing in the present study was 10.4 weeks. Early weight-bearing is an important factor contributing to successful rehabilitation and patient satisfaction. Several authors have emphasized that intramedullary interlocking nails provide sufficient stability to permit progressive weight-bearing without compromising fracture healing. Early ambulation not only accelerates recovery but also reduces the risk of complications associated with prolonged immobilization, including deep vein thrombosis, muscle wasting, and joint stiffness.

Radiological assessment revealed satisfactory alignment in 96% of patients. Maintenance of alignment is critical for achieving optimal functional outcomes and preventing long-term complications such as gait abnormalities and post-traumatic arthritis. The low incidence of malalignment observed in the present study reflects the effectiveness of interlocking screw fixation in controlling rotational and axial instability, particularly in comminuted and unstable fracture patterns.

Despite the overall favorable outcomes, certain complications were observed. Anterior knee pain was the most common complication, affecting 12% of patients. This finding is comparable to previous reports that have identified anterior knee pain as a frequent postoperative complaint following tibial nailing. Potential causes include irritation of the patellar tendon, injury to the infrapatellar branch of the saphenous nerve, prominence of the nail entry point, and postoperative scarring. Although most cases were mild and manageable conservatively, anterior knee pain remains an important consideration during patient counseling and postoperative follow-up.

Delayed union occurred in 8% of patients, while non-union was observed in 2%. These rates are within the range reported in the orthopedic literature. Factors contributing to delayed healing may include fracture comminution, soft tissue injury, smoking, infection, and inadequate biological response. The low non-union rate observed in the present study further supports the effectiveness of intramedullary nailing in promoting fracture healing.

Infectious complications were relatively uncommon, with superficial infection occurring in 5% of patients and deep infection in only 1%. Strict adherence to aseptic surgical techniques, timely administration of prophylactic antibiotics, and careful postoperative wound care may have contributed to the low infection rates. Similar findings have been reported in other prospective studies evaluating intramedullary nailing for tibial fractures.

The present study demonstrated significant improvement in pain scores during the follow-up period. Reduction in pain is a key indicator of successful fracture healing and functional recovery. The progressive decline in Visual Analogue Scale (VAS) scores observed from the immediate postoperative period to the final follow-up suggests effective stabilization and satisfactory rehabilitation.

The findings of this study have important clinical implications. Intramedullary interlocking nailing provides reliable fixation, promotes early rehabilitation, and achieves high rates of fracture union with acceptable complication rates. The procedure is particularly advantageous for displaced and unstable tibial shaft fractures, allowing patients to return to daily activities and occupational responsibilities more rapidly than many alternative treatment methods.

Limitations of the Study

The study has several limitations. First, it was conducted at a single tertiary care center, which may limit the generalizability of the findings. Second, the sample size was relatively modest, and a larger multicentric study may provide more representative results. Third, the follow-up period was limited to one year, which may not fully capture long-term complications or functional outcomes. Finally,

the absence of a comparison group treated with alternative fixation methods limits direct comparison of treatment efficacy.

Conclusion of Discussion

The present study demonstrates that intramedullary interlocking nailing is an effective and dependable treatment modality for tibial shaft fractures. The technique achieved a high fracture union rate, satisfactory radiological alignment, early weight-bearing, and excellent-to-good functional outcomes in the majority of patients. Complications were relatively infrequent and manageable. These findings support the continued use of intramedullary nailing as the treatment of choice for appropriately selected tibial shaft fractures and emphasize its role in facilitating successful clinical and radiological recovery.

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