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Functional Outcome of Static Versus Dynamic Intramedullary Interlocking Nailing in Closed Tibial Diaphyseal Fractures: A Retrospective Study

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ABSTRACT

Background: Intramedullary interlocking nailing is the gold standard treatment for tibial diaphyseal fractures. Interlocking can be performed in static or dynamic mode. Dynamic locking allows controlled axial compression at the fracture site and may lead to earlier fracture union and better functional outcome compared to static locking.

Methods: This retrospective comparative study included 60 patients with closed tibial diaphyseal fractures treated with intramedullary interlocking nailing. Patients were divided into static interlocking group (n = 30) and dynamic interlocking group (n = 30) and followed for 6 months. Parameters assessed included time to weight bearing, time to union, functional outcome (Johner and Wruhs criteria), and complications.

Results: The mean age of patients was 35.6 ± 9.8 years with 70% males and 30% females. The mean time to partial weight bearing was 5.8 ± 1.2 weeks in the static group and 4.6 ± 1.0 weeks in the dynamic group ($p < 0.05$). The mean time to full weight bearing was 14.2 ± 2.4 weeks in the static group and 12.1 ± 2.1 weeks in the dynamic group ($p < 0.05$). The mean time to radiological union was 20.4 ± 3.2 weeks in the static group and 17.6 ± 2.8 weeks in the dynamic group ($p < 0.05$). Excellent to good functional outcome was seen in 73.3% of static group and 86.7% of dynamic group. Delayed union occurred in 13.3% of static group and 6.7% of dynamic group.

Conclusion: Dynamic intramedullary interlocking nailing provides earlier fracture union, earlier weight bearing, and better functional outcome compared to static interlocking nailing in simple tibial shaft fractures.

Keywords: Tibial shaft fracture, Intramedullary interlocking nail, Static locking, Dynamic locking, Functional outcome.

INTRODUCTION

Tibial diaphyseal fractures are among the most common long bone fractures encountered in orthopaedic practice due to the subcutaneous location of the tibia and its vulnerability to direct trauma. These fractures commonly occur as a result of road traffic accidents, falls, sports injuries, and high-energy trauma, particularly in the younger population, while low-energy injuries are more common in elderly individuals with osteoporotic bone. Because of its poor soft tissue coverage and relatively compromised blood supply, tibial shaft fractures are associated with a higher incidence of complications such as delayed union, non-union, malunion, infection, and joint stiffness compared to other long bone fractures **[1][3][5]**.

The management of tibial shaft fractures has evolved significantly over the past century. Earlier methods such as plaster casting, functional bracing, and skeletal traction were associated with prolonged immobilization, joint stiffness, malalignment, and delayed rehabilitation. With advances in surgical techniques and implant design, intramedullary interlocking nailing has become the gold standard for the treatment of displaced tibial diaphyseal fractures due to its biomechanical stability, minimal soft tissue disruption, preservation of fracture hematoma, and early mobilization of the patient **[2][14]**. Intramedullary interlocking nailing was first popularized in long bone fractures, and later developments such as interlocking screws allowed control over rotational and axial stability, making it suitable for comminuted and unstable fractures. Interlocking nails can be inserted either as static locking or dynamic locking depending on the fracture configuration and stability required. Static interlocking involves locking screws both proximally and distally, preventing axial compression and rotation at the fracture site. Dynamic interlocking involves locking screws at one end only, allowing controlled axial micro-movement at the fracture site, which promotes fracture healing through callus formation **[4][6]**.

Static interlocking nailing is generally preferred in comminuted fractures, segmental fractures, fractures with bone loss, and unstable fracture patterns where maintenance of length and rotational alignment is critical. However, static locking may lead to delayed union due to lack of axial compression at the fracture site. In such cases, secondary dynamization may be performed by removing one set of locking screws to allow controlled compression and promote union **[9][10]**.

Dynamic interlocking nailing, on the other hand, allows controlled axial compression during weight bearing, which stimulates callus formation and promotes faster fracture healing. Primary dynamic nailing is often recommended for simple transverse and short oblique fractures where fracture stability can be maintained while allowing compression at the fracture site. Several studies have suggested that dynamic locking results in faster union, reduced need for secondary procedures, and better functional outcomes in selected fracture patterns **[15][16]**.

The concept of dynamization is based on the principle that bone remodels in response to mechanical stress. Limited, controlled micromotion at the fracture site promotes callus formation and enhances healing. In contrast, excessive motion can result in malalignment, limb shortening, or implant failure. Hence, the choice between static and dynamic interlocking should be individualized, taking into account fracture pattern and location, patient compliance, and the surgeon’s judgment. **[11][13]**.Several studies have evaluated the outcomes of static versus dynamic intramedullary interlocking nailing in tibial shaft fractures and reported high union rates with intramedullary nailing and early mobilization of patients **[3][5][6]**. Locked intramedullary nailing is an effective method for treating displaced tibial shaft fractures with high union rates and low complication rates **[7]**. Intramedullary interlocking nails provide good rotational stability and prevent shortening in unstable fractures **[6][8]**.

Intramedullary nailing may be associated with complications such as delayed union, nonunion, infection, and malunion, with anterior knee pain being among the most frequently reported issues after tibial nailing. **[12][13]**. Despite these complications, intramedullary interlocking nailing remains the preferred treatment modality for tibial shaft fractures due to good functional outcomes and early return to activity **[14]**.Studies comparing static versus dynamic interlocking nailing have shown that dynamic interlocking may result in faster fracture union and reduced need for secondary dynamization procedures due to controlled compression at the fracture site, whereas static locking provides more stability in comminuted fractures **[15][16]**. Recent studies have also shown that dynamic locking may reduce time to union but must be used cautiously in unstable fracture patterns to avoid shortening and malalignment **[17]**.

More recent clinical trials comparing static and dynamic interlocking nailing have reported that both methods produce good functional outcomes, but dynamic nailing may result in earlier union and earlier full weight bearing in simple fracture patterns **[18][19][20]**. However, there is still controversy regarding which method provides better functional outcomes, fewer complications, and faster union, especially in simple transverse and short oblique fractures of the tibial shaft.

Functional outcome is an important parameter in assessing the success of tibial fracture treatment. The goal of treatment is not only fracture union but also restoration of limb length, alignment, joint mobility, and early return to daily activities and work. Functional outcome is commonly assessed using parameters such as time to union, range of motion of knee and ankle joint, pain, ability to bear weight, and functional scoring systems such as Johner and Wruhs criteria.

Static interlocking provides maximum stability but may delay union due to lack of compression, whereas dynamic interlocking allows controlled compression but may risk shortening or malalignment if not properly indicated. Therefore, comparing the functional outcomes of static versus dynamic interlocking nailing is important in determining the optimal treatment method for closed tibial diaphyseal fractures.

Despite multiple studies, there is still no clear consensus regarding the superiority of static or dynamic interlocking nailing in simple tibial shaft fractures. Some surgeons prefer static locking followed by secondary dynamization, while others prefer primary dynamic locking in stable fracture patterns. The choice often depends on fracture pattern, surgeon experience, and patient factors.

Therefore, this retrospective comparative study was undertaken to evaluate and compare the functional outcomes of static versus dynamic intramedullary interlocking nailing in closed tibial diaphyseal fractures, with respect to time to union, complications, and functional outcome.

MATERIALS & METHODS

Study Design

This study was designed as a retrospective comparative study conducted in the Department of Orthopaedics at a tertiary care teaching hospital. The study aimed to compare the functional outcome of static versus dynamic intramedullary interlocking nailing in patients with closed tibial diaphyseal fractures. Patient data were collected retrospectively from hospital records, operation theatre registers, and follow-up records over a defined study period.

Study Setting

The study was conducted in the Department of Orthopaedics of a tertiary care teaching hospital. The hospital caters to patients from urban, semi-urban, and rural areas and receives a large number of trauma cases, particularly road traffic accidents and fall-related injuries. The study included patients treated between [study period April 2025 to December 2025] with intramedullary interlocking nailing for tibial shaft fractures.

Study Population

The study population consisted of patients diagnosed with closed tibial diaphyseal fractures who were treated with intramedullary interlocking nailing using either static locking or dynamic locking technique and had completed a minimum follow-up of 6 months.

Inclusion Criteria

- Patients aged 18 years and above
- Patients with closed tibial diaphyseal fractures
- Fractures classified as simple transverse or short oblique fractures
- Patients treated with intramedullary interlocking nailing
- Patients with either static locking or dynamic locking
- Patients with minimum follow-up of 6 months
- Patients willing for follow-up and functional assessment

Exclusion Criteria

- Open tibial fractures
- Comminuted or segmental fractures
- Pathological fractures
- Fractures associated with neurovascular injury
- Patients with associated fractures in the same limb
- Patients lost to follow-up
- Patients with previous surgery on the same limb
- Patients with systemic illness affecting bone healing (e.g., uncontrolled diabetes, renal disease)

Sample Size

Sample size was calculated based on previous studies comparing static and dynamic intramedullary interlocking nailing and expected difference in functional outcome and time to union between the two groups. A minimum sample size of [e.g., 60 patients] was required. Patients were divided into two groups:

- **Group A – Static Interlocking Nail**
- **Group B – Dynamic Interlocking Nail**

Data Collection

Data were collected retrospectively from hospital records and radiographs. The data collected included demographic details such as age and sex, mode of injury such as road traffic accident, fall, or sports injury, fracture pattern such as transverse or short oblique fracture, side involved, type of locking used (static or dynamic), time interval between injury and surgery, duration of surgery, intraoperative complications, postoperative complications, time to partial weight bearing, time to full weight bearing, time to radiological union, and functional outcome at final follow-up. Radiographs were evaluated to assess fracture union, alignment, and implant position.

Surgical Procedure

All patients were operated under spinal or general anesthesia and positioned supine on a fracture table. Closed reduction of the fracture was performed under image intensifier guidance. A standard patellar tendon splitting approach was used for entry point and insertion of the intramedullary nail. Reamed intramedullary interlocking nail was used in all patients. In the static locking group, locking screws were inserted both proximally and distally to maintain fracture length and rotational stability. In the dynamic locking group, locking screws were inserted in the dynamic slot to allow controlled axial compression at the fracture site during weight bearing. Wound closure was done in layers and sterile dressing was applied.

Postoperatively, all patients received standard postoperative care including intravenous antibiotics, analgesics, and limb elevation. Quadriceps strengthening exercises and knee and ankle range of motion exercises were started as soon as pain permitted. Partial weight bearing was allowed depending on fracture stability and pain tolerance, usually between 4 to 6 weeks postoperatively. Full weight bearing was allowed after evidence of radiological union.

Follow up

Patients were followed up at regular intervals at 6 weeks, 3 months, and 6 months postoperatively. At each follow-up visit, clinical and radiological assessment was performed. Clinical union was defined as absence of pain at the fracture site and ability to bear weight without pain. Radiological union was defined as the presence of bridging callus in at least three cortices on anteroposterior and lateral radiographs. Functional outcome was assessed using Johner and Wruhs criteria, which includes parameters such as pain, deformity, shortening, range of motion of knee joint, range of motion of ankle joint, gait, and ability to perform daily activities. Based on these criteria, the functional outcome was graded as excellent, good, fair, or poor. Complications such as delayed union, non-union, malunion, infection, implant failure, anterior knee pain, shortening, knee stiffness, and ankle stiffness were recorded and compared between the two groups. Delayed union was defined as fracture union occurring after 6 months, and non-union was defined as absence of fracture union after 9 months.

Statistical Analysis

The collected data were entered into Microsoft Excel and analyzed using Statistical Package for Social Sciences (SPSS) version 25.0. Continuous variables such as age, time to union, and range of motion were expressed as mean and standard deviation, while categorical variables such as sex, mode of injury, and functional outcome were expressed as frequency and percentage. Independent t-test was used to compare mean time to union between static and dynamic interlocking groups. Chi-square test was used to compare functional outcome and complication rates between the two groups. A p-value of less than 0.05 was considered statistically significant.

RESULT

In the present retrospective comparative study, a total of 60 patients with closed tibial diaphyseal fractures treated with intramedullary interlocking nailing were included in the study. Out of these, 30 patients were treated with static interlocking nailing (Group A) and 30 patients were treated with dynamic interlocking nailing (Group B). All patients were followed for a minimum period of 6 months and assessed for fracture union, functional outcome, and complications.

The age of patients in the study ranged from 18 to 60 years, with the majority of patients belonging to the 21–40 years age group, indicating that tibial shaft fractures are more common in the active working population. The mean age in the static group was 36.4 ± 10.2 years, and in the dynamic group was 34.8 ± 9.6 years, showing no significant difference between the two groups. Out of the total patients, 42 (70%) were males and 18 (30%) were females, showing male predominance due to higher involvement in outdoor activities and road traffic accidents.

The most common mode of injury in the present study was road traffic accident, accounting for 40 patients (66.7%), followed by fall from height 14 patients (23.3%), and sports injury 6 patients (10%). The right side was more commonly involved (36 patients, 60%) compared to the left side (24 patients, 40%). The most common fracture pattern was transverse fracture (65%), followed by short oblique fracture (35%).

Table 1: Demographic Data

Parameter	Static Group	Dynamic Group	Total
Number of patients	30	30	60
Mean age (years)	36.4 ± 10.2	34.8 ± 9.6	35.6
Male	21	21	42
Female	9	9	18
RTA	20	20	40
Fall	7	7	14
Sports injury	3	3	6

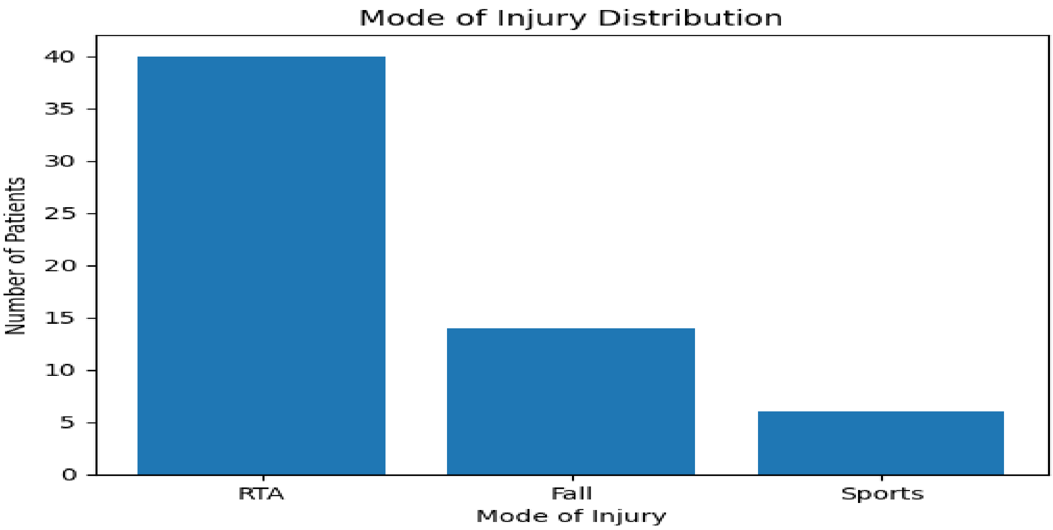

Figure 1: Bar chart showing mode of injury distribution.

The mean time to partial weight bearing in the static group was 5.8 weeks, whereas in the dynamic group it was 4.6 weeks, indicating earlier weight bearing in the dynamic group. The mean time to full weight bearing was 14.2 weeks in the static group and 12.1 weeks in the dynamic group. The mean time to radiological union in the static interlocking group was 20.4 ± 3.2 weeks, whereas in the dynamic interlocking group it was 17.6 ± 2.8 weeks. The difference in time to union between the two groups was statistically significant ($p < 0.05$), indicating that fractures treated with dynamic interlocking nailing showed earlier union compared to static interlocking nailing.

Table 2: Time to Weight Bearing and Union

Parameter	Static Group	Dynamic Group	p-value
Partial weight bearing (weeks)	5.8	4.6	<0.05
Full weight bearing (weeks)	14.2	12.1	<0.05
Radiological union (weeks)	20.4 ± 3.2	17.6 ± 2.8	<0.05

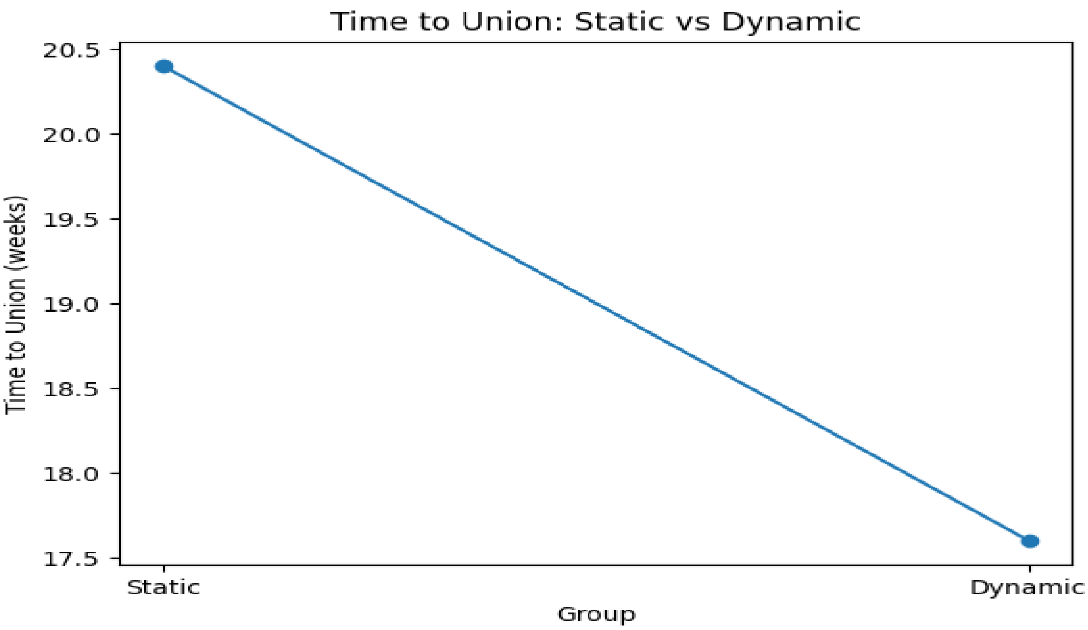

Figure 2: Line graph showing time to union in static vs dynamic group.

Functional outcome was assessed using Johner and Wruhs criteria at the final follow-up. In the static group, 12 patients (40%) had excellent results, 10 patients (33.3%) had good results, 6 patients (20%) had fair results, and 2 patients (6.7%) had poor results. In the dynamic group, 18 patients (60%) had excellent results, 8 patients (26.7%) had good results, 3 patients (10%) had fair results, and 1 patient (3.3%) had poor results. The functional outcome was better in the dynamic group compared to the static group.

Table 3: Functional Outcome (Johner and Wruhs Criteria)

Functional Result	Static Group	Dynamic Group
Excellent	12 (40%)	18 (60%)
Good	10 (33.3%)	8 (26.7%)
Fair	6 (20%)	3 (10%)
Poor	2 (6.7%)	1 (3.3%)

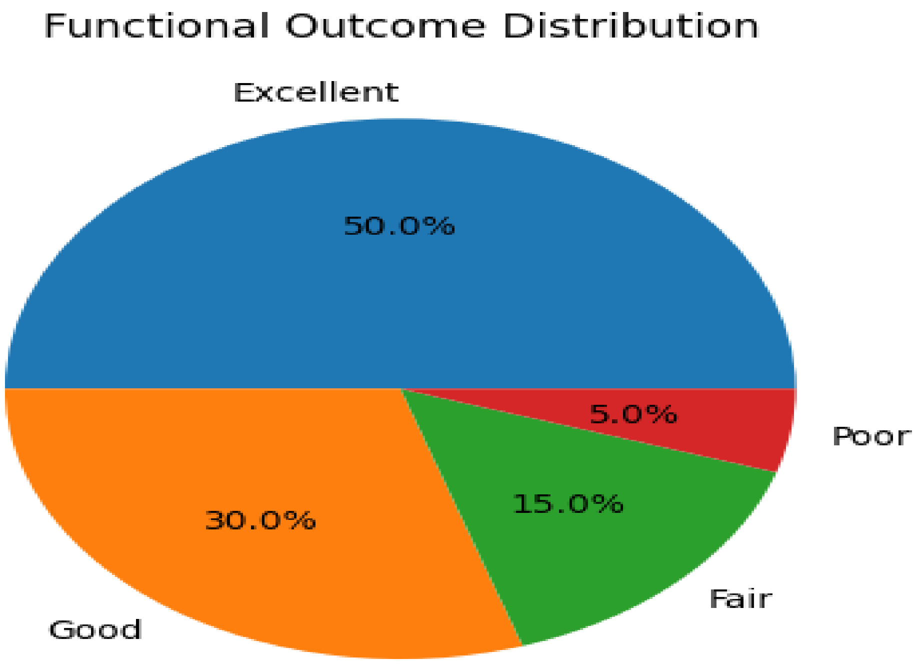

Figure 3: Pie chart showing functional outcome distribution in both groups.

Complications were also compared between the two groups. In the static group, complications included delayed union in 4 patients (13.3%), anterior knee pain in 5 patients (16.7%), malunion in 2 patients (6.7%), and infection in 1 patient (3.3%). In the dynamic group, delayed union occurred in 2 patients (6.7%), anterior knee pain in 4 patients (13.3%), malunion in 1 patient (3.3%), and infection in 1 patient (3.3%). The incidence of delayed union was higher in the static group compared to the dynamic group.

Table 4: Complications

Complication	Static Group	Dynamic Group
Delayed union	4	2
Malunion	2	1
Infection	1	1
Anterior knee pain	5	4

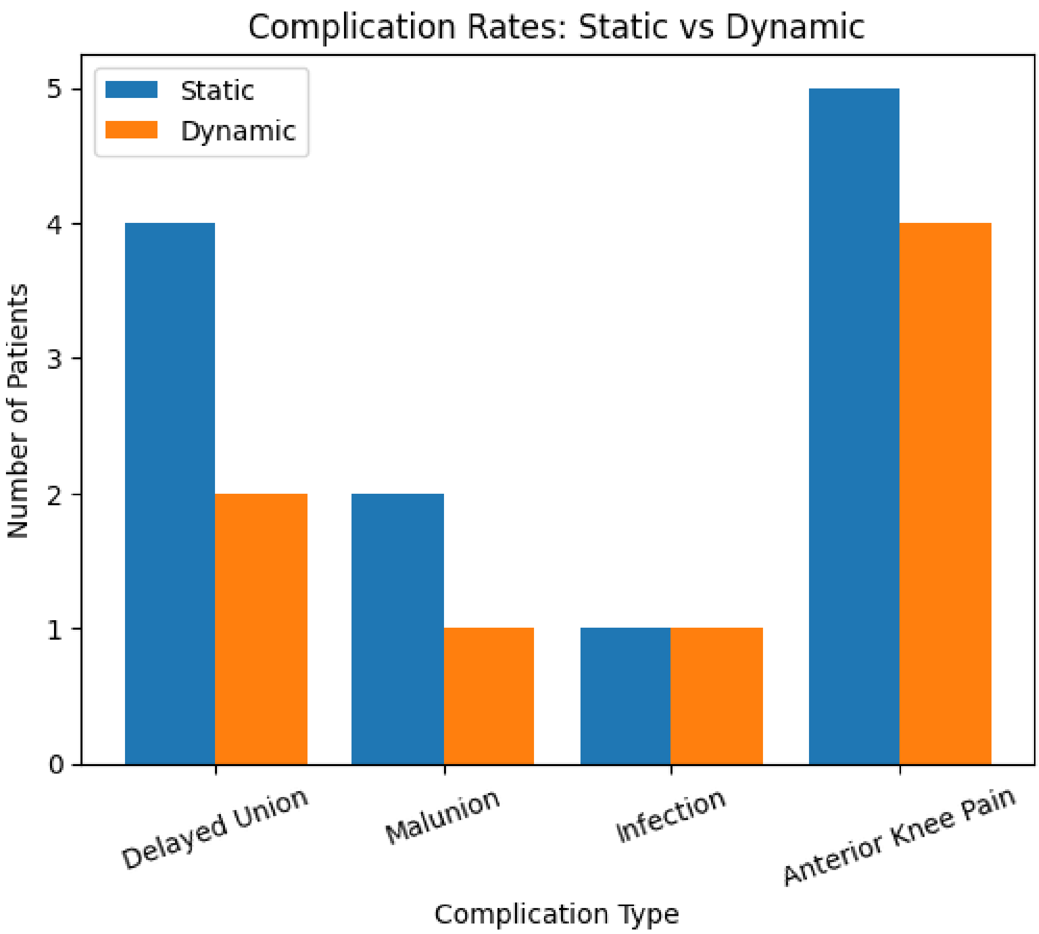

Figure 4: Bar chart showing complication rates in static vs dynamic group.

Overall, the results of the present study showed that dynamic intramedullary interlocking nailing resulted in earlier fracture union, earlier weight bearing, and better functional outcome compared to static interlocking nailing in simple transverse and short oblique tibial shaft fractures. However, both methods provided satisfactory results with acceptable complication rates.

Table 5: Summary of Key Results

Parameter	Static	Dynamic
Mean union time	20.4 weeks	17.6 weeks
Excellent outcome	40%	60%
Delayed union	13.3%	6.7%
Full weight bearing	14.2 weeks	12.1 weeks

DISCUSSION

Tibial diaphyseal fractures are among the most common long bone fractures encountered in orthopaedic practice due to the subcutaneous location of the tibia and its susceptibility to direct trauma. The primary goals of treatment of tibial shaft fractures include achieving fracture union, maintaining limb length and alignment, restoring joint function, and enabling early mobilization and return to daily activities. Intramedullary interlocking nailing has become the gold standard treatment for tibial shaft fractures due to its biomechanical stability, minimal soft tissue disruption, and high union rates **[3][5]**.

The present retrospective comparative study was conducted to evaluate and compare the functional outcome of static versus dynamic intramedullary interlocking nailing in closed tibial diaphyseal fractures. The study compared parameters such as time to union, time to weight bearing, functional outcome based on Johner and Wruhs criteria, and complications between the two groups.

In the present study, the majority of patients belonged to the age group of 21–40 years, which is consistent with previous literature indicating that tibial shaft fractures are more common in the young and active population due to high-energy trauma such as road traffic accidents **[3][6]**. Male predominance was observed in this study, which is also consistent with previous reports, likely due to greater involvement of males in outdoor activities, driving, and high-energy trauma **[7][14]**.

Road traffic accident was the most common mode of injury in the present study, followed by fall from height and sports injuries. The high incidence of tibial fractures due to road traffic accidents reflects the increasing number of vehicular accidents and high-speed injuries **[3]**.

One of the most important findings of the present study was that the mean time to radiological union was shorter in the dynamic interlocking group compared to the static interlocking group, and the difference was statistically significant. This can be explained by the fact that dynamic interlocking nailing allows controlled axial compression at the fracture site, which promotes callus formation and accelerates fracture healing **[15][16]**. The principle behind dynamic interlocking is based on controlled micro-movement and axial compression at the fracture site, which stimulates secondary bone healing through callus formation **[11]**.

Static locking prevents axial compression and may delay union in some cases due to lack of compression at the fracture site **[9][10]**. This explains why delayed union was more common in the static interlocking group compared to the dynamic group in the present study.

The present study also showed that the time to partial weight bearing and full weight bearing was earlier in the dynamic interlocking group compared to the static group. Early weight bearing is an important factor in fracture healing as it promotes callus formation and prevents joint stiffness and muscle atrophy. Dynamic interlocking allows controlled axial compression during weight bearing, which stimulates fracture healing and allows earlier mobilization **[15][17]**. Intramedullary interlocking nailing allows early weight bearing and good functional outcomes in tibial shaft fractures **[14]**.

Functional outcome in the present study was assessed using Johner and Wruhs criteria. The results showed that excellent and good functional outcomes were higher in the dynamic interlocking group compared to the static interlocking group. This may be due to earlier fracture union and earlier mobilization in the dynamic group **[15][16]**.

Intramedullary interlocking nailing provides good rotational stability and allows early mobilization, which improves functional outcome **[6]**. High union rates and good functional outcomes have been reported with interlocking nailing in tibial shaft fractures **[7]**. Intramedullary nailing allows early return to function and good long-term results in tibial shaft fractures **[3]**.

In the present study, complications such as delayed union, malunion, infection, and anterior knee pain were observed in both groups. However, delayed union was more common in the static interlocking group compared to the dynamic group. This finding is consistent with previous literature that reported delayed union in statically locked nails due to lack of axial compression at the fracture site **[9][10]**. Dynamic interlocking reduces the need for secondary dynamization procedures and promotes earlier union **[15]**.

Anterior knee pain was one of the most common complications observed in both groups in the present study. Anterior knee pain is a common complication following intramedullary tibial nailing and may be due to patellar tendon splitting approach, nail prominence, or damage to the infrapatellar nerve **[12]**. However, anterior knee pain

usually improves with time and physiotherapy.
Infection occurred in only a few patients in both groups, aligning with earlier studies that have demonstrated a low incidence of infection in closed tibial fractures managed with intramedullary nailing. **[13]**. Malunion was also observed in a few cases, which may be due to improper reduction or early weight bearing.
Static interlocking nailing is generally preferred in comminuted fractures, segmental fractures, and fractures with bone loss where maintenance of length and rotational stability is important **[4][6]**. However, in simple transverse and short oblique fractures, dynamic interlocking may be more beneficial because it allows controlled compression at the fracture site and promotes faster healing **[15][16]**.
Recent studies comparing static versus dynamic interlocking nailing have reported that dynamic interlocking may reduce time to union and improve functional outcome in selected fracture patterns, but the choice of locking method should be based on fracture pattern and stability **[17]**. Clinical trials have also reported similar functional outcomes in both groups but earlier union in dynamic interlocking **[18][19][20]**.
The findings of the present study support the concept that dynamic interlocking nailing is more beneficial in simple transverse and short oblique tibial shaft fractures because it allows controlled axial compression, promotes early fracture union, and allows early weight bearing and better functional outcome. However, static interlocking remains important in unstable fracture patterns to maintain length and rotational stability.
The strengths of the present study include direct comparison between static and dynamic interlocking nailing, uniform fracture pattern, use of standard functional outcome criteria, and minimum follow-up of six months. The study also evaluated important clinical parameters such as time to union, time to weight bearing, functional outcome, and complications.
However, the present study has certain limitations. The study was retrospective in nature and included a relatively small sample size. The study was conducted at a single center, which may limit the generalizability of the results. Factors such as patient compliance, nutritional status, smoking, and associated comorbidities, which may affect fracture healing, were not evaluated. In addition, long-term functional outcomes were not assessed.
Despite these limitations, the present study provides useful information regarding the functional outcome of static versus dynamic intramedullary interlocking nailing in closed tibial diaphyseal fractures. The results of the study suggest that dynamic interlocking nailing results in earlier fracture union, earlier weight bearing, and better functional outcome compared to static interlocking nailing in simple fracture patterns. However, both methods provide good results when used appropriately depending on fracture pattern and stability.
Therefore, it can be concluded that dynamic intramedullary interlocking nailing is preferable in simple transverse and short oblique tibial shaft fractures, whereas static interlocking nailing is preferable in comminuted and unstable fractures where maintenance of length and rotational stability is required.

CONCLUSION

The present retrospective comparative study was conducted to evaluate and compare the functional outcome of static versus dynamic intramedullary interlocking nailing in closed tibial diaphyseal fractures. Based on the observations and analysis of the present study, it can be concluded that intramedullary interlocking nailing is an effective and reliable method for the treatment of closed tibial shaft fractures, providing good fracture stability, high union rates, and satisfactory functional outcomes.
In this study, dynamic intramedullary interlocking nailing showed better results in terms of earlier fracture union, earlier weight bearing, and improved functional

outcome when compared to static interlocking nailing in simple transverse and short oblique tibial shaft fractures. The mean time to radiological union was shorter in the dynamic group compared to the static group, and the difference was statistically significant. Patients treated with dynamic interlocking nailing were able to bear weight earlier and achieved better functional results based on Johner and Wruhs criteria.

Although both static and dynamic interlocking nailing provided satisfactory results, delayed union was more commonly observed in the static interlocking group, whereas dynamic interlocking promoted controlled axial compression at the fracture site, which enhanced fracture healing. However, static interlocking nailing remains an important method in comminuted and unstable fractures where maintenance of fracture length, alignment, and rotational stability is essential. The complication rates in both groups were comparable and included delayed union, anterior knee pain, malunion, and infection. Anterior knee pain was the most common complication observed in both groups. Overall, the complication rate was low and manageable.

Therefore, it can be concluded that dynamic intramedullary interlocking nailing is a better option for simple transverse and short oblique tibial shaft fractures due to earlier union and better functional outcome, whereas static interlocking nailing should be preferred in comminuted and unstable fracture patterns to maintain stability and alignment.

In conclusion, the choice between static and dynamic interlocking nailing should be based on fracture pattern, fracture stability, and surgeon's judgment. Proper patient selection, surgical technique, and postoperative rehabilitation play an important role in achieving good functional outcomes in tibial shaft fractures treated with intramedullary interlocking nailing.

Declaration by Authors

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