Exp Biomed Res 2025; 8(3): 138-148 **https://doi.org/ 10.30714/j-ebr.2025.244**

Experimental Biomedical Research ***Original article***

Comparison of intramedullary nailing versus plate fixation in tibial shaft fractures: A retrospective clinical and radiological analysis

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ABSTRACT

Aim: Treatment for tibial shaft fractures typically involves plate fixation or intramedullary nailing (IMN). Our objective in this study was to compare the radiological and clinical outcomes of plate fixation with IMN for tibial shaft fractures

Method: Fifty-two patients (33 males, 19 females; mean age 36.9±13.8 years; range, 16 to 68 years) who underwent surgery for tibial shaft fracture) between 2003-2011 were retrospectively evaluated. Patients were compared in terms of union time, radiological healing time, weight-bearing time, infection, malunion, and malalignment. Final clinical evaluations of the patients was performed according to the R. Johner and O. Wrush criteria.

Results: The average time to weight-bearing was significantly longer in the plate fixation group (7.63±2.27 weeks) compared to the intramedullary nailing group (4.04±1.06 weeks, p=0.000). Similarly, the radiological healing time was longer with plate fixation (12.37 months) by 4.30 months (p=0.000). There were no significant differences in pain between the groups (p=0.535), walking ability (p=0.431), joint range of motion (p=0.243), or strenuous activities (p=0.449). According to the R. Johner and O. Wrush criteria, 68% of patients in both groups achieved excellent outcomes, with the remaining patients having a similar distribution between good and fair categories.

Conclusions: The study's findings demonstrated that, in terms of clinical and functional results, both treatment approaches are comparable. Aligning seems to be easier with plates, while the healing period appears to be shorter with IMN. To shed further light on these matters, Randomized Prospective evaluation may be recommended and it may provide detailed information on the costs/expenses associated with these fractures.

Keywords: Tibia shaft fracture, intramedullary nailing, minimally invasive plate osteosynthesis.

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Received: 2024-10-15 / Revisions: 2025-01-02

Accepted: 2025-01-13 / Published: 2025-07-01

1. Introduction

Tibial fractures are clinically significant due to their anatomical characteristics, greater exposure to trauma compared to other bones, and the variety of treatment options available. The anterior-medial surface of the tibia has relatively thin soft tissue coverage, making it more susceptible to open fractures [1]. In addition, due to the limited soft tissue surrounding the tibia, the blood supply to the tibia is less compared to other long bones. High-energy tibial fractures are often accompanied by complications such as compartment syndrome, and neural and vascular injuries [2]. Given the hinge joint characteristic of the knee and ankle, rotational deformities following a fracture are not easily recoverable and require special care during fracture reduction to prevent such deformities. Due to these factors, tibial fractures frequently have complications like delayed union, nonunion, or infection. Therefore, their treatment requires a more thoughtful approach [3].

Treatment options for tibial shaft fractures include closed reduction and casting, functional bracing, open reduction and internal fixation with plates and screws, external fixation, and intramedullary nailing. Determining the optimal treatment requires careful consideration of fracture morphology, the force of impact, the mechanical properties of the bone, the patient's age and general health, and most importantly, the condition of the soft tissue [4]. For the majority of displaced tibial fractures, intramedullary nailing (IMN) is the primary treatment option. As a load-sharing implant rather than a load-bearing implant, firsdt of all they are biomechanically superior to plates. Secondly, the method does not interfere with the natural process of bone mending. However, as the intramedullary device can be difficult to manage), there is a high rate of malalignment (5% to 58%) when treating proximal and distal tibial fractures. Therefore many publications recommend plate fixation to prevent these complications, especially in proximal and distal tibial shaft fractures [5]. Anatomic reduction and stable fixation can be achieved with standard open reduction and plate fixation, but there is a significant risk of non-union and infection [6]. The drawbacks of traditional plating are reduced with MIPO (minimally invasive plate osteosynthesis), which also results in better bone union, less wound healing time, and fewer infection complications. It also prevents anterior knee discomfort. Both IMN and MIPO have benefits and drawbacks, as previously mentioned. There are few studies comparing minimally invasive plating with IMN, although the ideal strategy is still remains controversial despite the successful use of this technique and its favorable outcomes with decreased rates of infection and malunion [7,8]. Hence, the purpose of this study is to assess the effectiveness of intramedullary nailing and minimally invasive plating in the treatment of tibial shaft fractures, as well as the consequences and results of each modality.

2. Materials and methods

2.1 Patients' demographics: Fifty-two patients with tibial fractures who admitted to the Orthopedics and Traumatology Clinic in Hamidiye Şişli Etfal Training and Research Hospital between 2003 and 2011 were included in the evaluation. Plate osteosynthesis was performed in 15 male and 12 female patients whereas intramedullary nailing was performed in 18 male and 7 female patients. In total 33 male and 19 female patients underwent surgical treatment.) Our Institutional Ethics Committee approved the study protocol and informed consent was obtained from all patients prior to study inclusion. This study was planned according to the STROBE guidelines and conducted in compliance with the principles of the Helsinki Declaration. Only patients who attended outpatient follow-up and had sufficient records in the archives were included in the study.

2.2 Inclusion and exclusion criteria: Cases with diaphyseal and metaphyseal-diaphyseal tibial fractures were included in the evaluation for the study. Following the emergency department admission, standard two-view (A-P and lateral) X-rays were obtained, capturing the joints proximal and distal to the fracture line. The study focused on cases resulting from high-energy mechanisms that were unstable following closed reduction and casting, often accompanied by varying degrees of soft tissue injury, which indicated the need for surgical intervention. Patients with multi-fragmentary diaphyseal fractures and proximal and distal metaphyseal fractures that did not extend into the joints were included unless they have been previously treated for the same reason. Only primary closed fractures or those classified as Gustilo-Anderson type 1 and 2 open fractures were taken into consideration for the study. Gustilo-Anderson type 3 fractures, previously treated fractures, pathological and periprosthetic fractures, malunions, and pseudoarthroses were excluded. Patients who did not attend follow-up appointments or refused to participate in the study were also excluded. Flow chart of patient's selection was given in Figure 1.

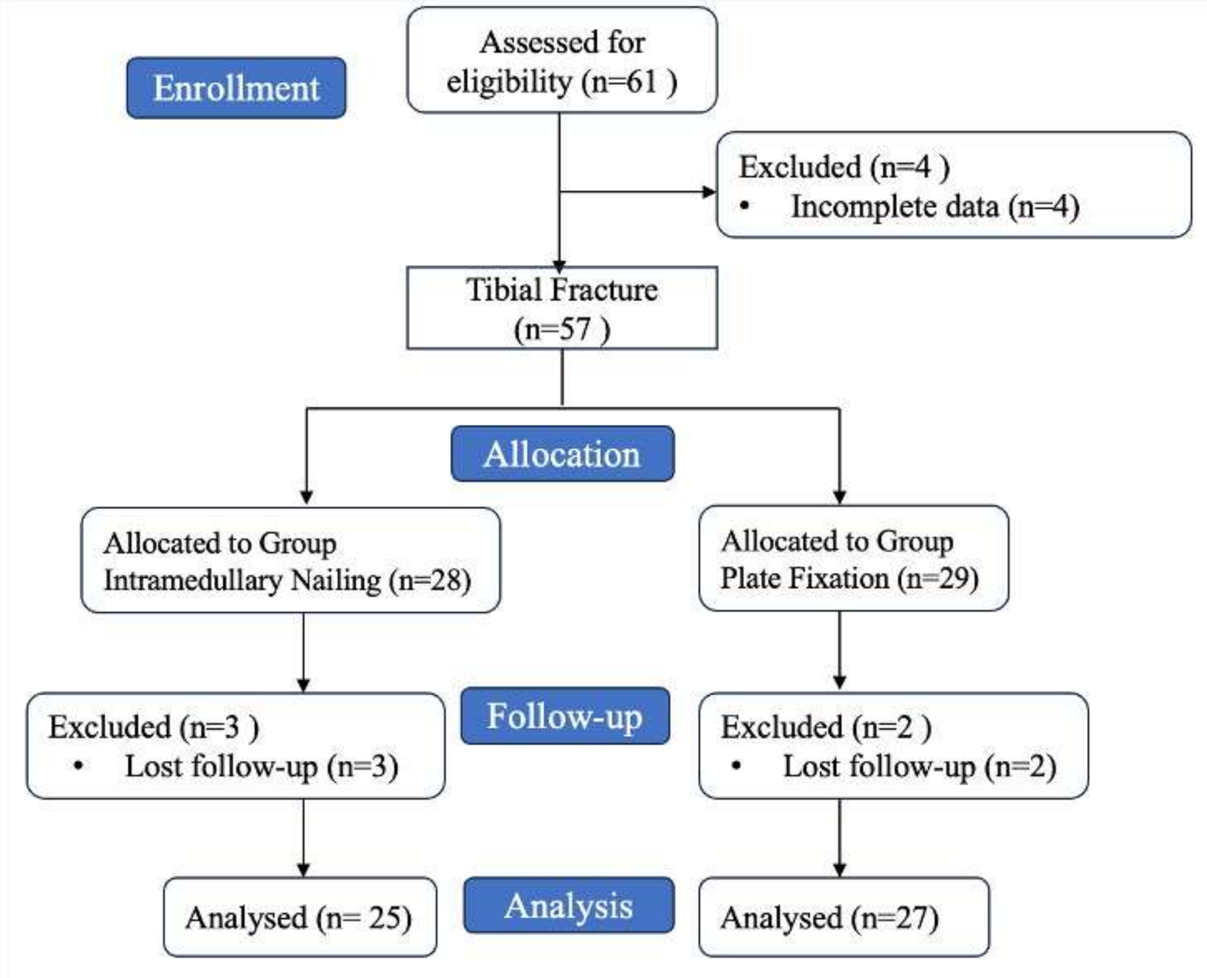

Figure 1. Flowchart of the patients.

2.3 Preoperative evaluation: Two-view X-rays were obtained, including the joints above and below the fracture line, as well as two-view X-rays of the contralateral limb. In the presence of open fractures, the wounds were classified according to the Gustilo-Anderson classification. For cases classified as Gustilo-Anderson type 1, debridement and irrigation with Betadine and isotonic saline were performed, followed by antibiotic prophylaxis with 1 g of Cefazolin-Na (4x1) for 3 days. For Gustilo-Anderson type 2 cases, Gentamicin (1x160 mg) was added to the Cefazolin regimen for prophylaxis. Patients underwent a closed reduction in the emergency room, and in cases of open fractures, saline irrigation was performed before splint application. None of the patients required temporary external fixation. All fractures were classified radiographically according to the AO classification.

Figure 2. Preoperative images (Figures A and B) of a 42-year-old male patient presenting after a motorcycle accident, and postoperative images (Figures C and D) following successful union.

Figure 3. Preoperative images (Figures A and B) of a 63-year-old male patient with a tibial fracture following a fall, and postoperative images (Figures C and D).

2.4 Surgical technique: Standard methods for the insertion of intramedullary nails (IMN) and the application of minimally invasive plate osteosynthesis (MIPO) were performed by the authors, all of whom were trained in these techniques. Images of one patient who underwent IMN are shown in Figure 2, while radiographs of a patient treated with plate osteosynthesis are displayed in Figure 3.

2.5 Postoperative evaluation and outcome assessment: Patients underwent follow-up the third and sixth weeks, and subsequently at six-week intervals until the fracture union. Postoperative X-ray examinations were performed, and angulation was measured by the surgeon. The absence of pain in the fracture site and the presence of callus tissue in at least three of the four cortices on radiographs were considered as indicators of fracture healing. Based on the clinical examination and radiographs showing fracture healing, patients were encouraged to bear weight. The patients were evaluated using the standards established by R. Johner and O. Wrush at their most recent follow-up (9) (Table 1).

Table 1. Classification of tibial shaft fractures and correlation with results after rigid internal fixation.

Category	Excellent	Good	Fair	Poor
Nonunion, Osteomyelitis, Amputation	None	None	None	Present
Deformity				
Varus/Valgus	None	2–5°	6–10°	>10°
Antecurvatum/Recurvatum	0–5°	6–10°	11–20°	>20°
Rotation	0–5°	6–10°	11–20°	>20°
Shortening	0–5 mm	6–10 mm	11–20 mm	>20 mm
Movement				
Knee	Normal	> 80%	> 75%	< 75%
Ankle	Normal	> 75%	> 50%	< 50%
Subtalar joint	> 75%	> 50%	< 50%	None
Neurovascular Dysfunction	None	Minimal	Moderate	Severe
Pain	None	Occasional	Moderate	Severe
Gait	Normal	Normal	Mild limp	Significant limp
Heavy activity	Possible	Limited	Severely limited	Impossible

2.6 Statistical analysis: Statistical analysis was performed using IBM SPSS version 23.0

software (IBM Corp., Armonk, NY, USA). Descriptive statistical methods (frequency, percentage, mean, standard deviation, and median) were utilized to evaluate the study data, and the Kolmogorov-Smirnov test was employed to assess the normality of distribution. For comparing categorical data, Pearson's Chi-square test and Fisher's Exact test were used. The Mann-Whitney U or t-tests were applied for intergroup comparisons of quantitative data, while the Wilcoxon signed-rank test was used for intragroup comparisons. Results were considered statistically significant at a 95% confidence interval, with $p < 0.05$, and highly significant at $p < 0.01$ and $p < 0.001$.

3.Results

Plate osteosynthesis was performed in 15 male and 12 female patients whereas intramedullary nailing was performed in 18 male and 7 female patients. In total 33 male and 19 female patients underwent surgical treatment.) The mean age of patients in the intramedullary nailing group was 36.1 years (range: 18-68), while in the plate fixation group, the youngest patient was 16 years old, the oldest patient was 63 years old with a mean age outcome of 32.9 years (range: 16-63).

In the group of patients treated with intramedullary nailing, 12 patients had fractures on the right side (48%), and 13 patients had fractures on the left side (52%). Among those treated with plating, 12 patients had left-sided fractures (44.4%) and 15 patients had right-sided fractures (55.5%). One patient in the intramedullary nailing group had an isolated tibial fracture, while the remaining 24 had combined tibia and fibula fractures. Additionally, one patient had a scapular fracture, and another had a fracture-dislocation of the left wrist. In the plating group, 3 patients had isolated tibial fractures, while the remaining 24 patients had combined tibia and fibula fractures. One patient also had a left calcaneus fracture. Among the evaluated patients, 5 had type 1 open fractures and 4 had type 2 open fractures. Of the patients with type 1 open fractures, 3 underwent intramedullary nailing, and 2 had plate osteosynthesis. For type 2 open fractures, 3 were treated with intramedullary nailing and 1 with plating. Regarding the etiology of the fractures, in the IMN group, 12 fractures caused by motorcycle and bicycle collisions, 4 from motor vehicle collisions (MVCs), and 9 from falls. In the plating group, 12 fractures were due to motorcycle and bicycle collisions, 4 from MVCs, and 11 from falls (Table 2).

Table 2. Patients' demographics.

Parameters	**Intramedullary nail N=25**	**Plate N=27**
Age	36.1 (18-68)	32.9 (16-63)
Gender		
Female/Male	7/18	12/15
Side		
Right/Left	12/13	15/12
Trauma type		
Motor vehicle collisions	4	4
Motorcycle and bicycle collisions	12	12
Fall	9	11

A total of 52 patients with tibial diaphysis fractures were clinically and radiologically evaluated. The complete union was achieved in all patients, with no cases of wound complications or osteomyelitis reported. The average follow-up duration for patients treated with intramedullary nailing was 30.5 months (range 4-88), while those treated with plate fixation had an average follow-up duration of 37.7 months (range 11-92). In the intramedullary nailing group, the earliest union was observed at week 6, with the latest at week 36 week. Compared to this, in patients with plate fixation, the earliest union was observed at week 8 and the latest at week 29. When the weight-bearing time was compared between the two groups, the mean time was significantly longer in patients with plate fixation at 7.63 ± 2.27 weeks compared to 4.04 ± 1.06 weeks for those treated with intramedullary nailing (*p* = 0.000). The mean radiological healing time for plate fixation patients was 12.37 months, which was significantly longer by 4.30 months compared to the intramedullary nailing group (*p* = 0.000). There were no significant differences between the two groups in terms of pain (*p* = 0.535), walking ability (p = 0.431), range of joint motion (*p* = 0.243), or strenuous activities (*p* = 0.449) (Table 3).

Table 3. The distribution of weight bearing and radiological healing according to groups.

Parameters	Plate	Intramedullary nail	*P* value
Weight-bearing (weeks)	7.63±2.27	4.04±1.06	*0.000*
Radiological healing (months)	12.37±5.4	4.3±1.32	*0.000*

We classified the fractures according to the AO (Arbeitsgemeinschaft für Osteosynthesefragen) classification system, which categorizes fractures based on the fracture line. In the AO classification, type A refers to simple fractures without fragmentation, type B refers to simple fractures with a butterfly fragment, and type C refers to segmental and multi-fragmented fractures. It can also be further subcategorized into 1 for spiral fractures, 2 for oblique fractures and 3 for transverse fractures.

According to this classification:

- In the intramedullary nailing group, out of 25 patients, 18 patients (72%) had type A fractures, 3 patients (12%) had type B fractures, and 4 patients (16%) had type C fractures.

- In the plating group, out of 27 patients, 21 patients (77.7%) had type A fractures, 5 patients (18.5%) had type B fractures, and 1 patient (3.7%) had a type C fracture (Table 4).

Table 4. The distribution of fractures according to the AO classification.

Type	Intramedullary nail (N/%)	Plate (N/%)	Total (N/%)
Type A	18 (%72)	21(%77.7)	39 (%75.0)
Type B	3 (%12)	5 (%18.5)	8 (%15.3)
Type C	4 (%16)	1 (%3.7)	5 (%9.6)
Total	25 (%100)	27 (%100)	52(%100)

The fracture levels were categorized as distal, mid-diaphyseal, and proximal. Among the fractures treated with intramedullary nailing, 6 fractures (24%) were located distally, 17 (68%) were mid-diaphyseal, and 2 (8%) were proximal. In the plating group, 13 fractures (48.1%) were distal, 9 (33.3%) were mid-diaphyseal, and 5 (18.5%) were proximal.

The time to operation varied depending on factors such as patient load, material availability, and the condition of the limb. Patients treated with intramedullary nailing were operated on between day 2-16 post-injury (mean 5.8 days), while patients treated with plating were operated on between days 220 post-injury (mean 7.6 days).

All patients treated with intramedullary nailing exhibited a normal range of motion in the ankle and subtalar joints. Two patients (8%) had knee flexion limited to 100º, while 23 patients (92%) had full knee mobility. Among patients treated with plate fixation, one patient (3%) had knee flexion limited to 100º, and 26 patients (96%) had full knee mobility. Additionally, four patients (14%) had restricted motion in the ankle joint (two patients with 10º and two with 15º of limitation). No patient in the intramedullary nailing group reported ankle pain; however, nine patients (36%) experienced knee pain (five had occasional pain, and four had moderate pain). In the plate fixation group, nine patients (33%) reported ankle pain (four had occasional pain and five had moderate pain), and four patients (14%)

had occasional knee pain. Five patients (20%) in the intramedullary nailing group and seven patients (25%) in the plate fixation group had uncertain limitations in their activities. Five patients in both the intramedullary nailing group (20%) and the plate fixation group (18%) reported limitations) in strenuous activities.

Based on these results, 17 patients (68%) in the intramedullary nailing group were rated as excellent, 4 patients (16%) as good, and 4 patients (16%) as fair. Similarly, in the plate fixation group, 18 patients (68%) were rated as excellent, 4 patients (14%) as good, and 5 patients (18%) as fair (Table 5).

Table 5. The classification of patients' clinical outcomes according to the R. Johner and O. Wrush criteria.

	Intramedullary nail	Plate
Excellent	17 (%68)	18 (%68)
Good	4 (%16)	4 (%14)
Fair	4 (%16)	5 (%18)

A significant difference in varus-valgus angulation was observed when each group was compared to the contralateral intact extremity (*p*=0.000). However, no significant difference was observed between the plate fixation group and the intramedullary nailing group (*p*>0.05) (Table 6).

Table 6. Comparison of the varus-valgus angles of the operated and healthy legs.

Groups	Varus-valgus angle		
	Operated leg	Healthy leg	*P* value
Intramedullary nail	3.52±2.2	0.44±1.08	*0,000*
Plate	2.81±2.4	0.85±0.78	*0,000*

In both groups, a significant difference was found in the antecurvation-recurvation angles when comparing the operated side to the intact side (Plate: *p*=0.022, IMN: *p*=0.000). However, when comparing the two patient groups based on this variable, no significant difference was observed (*p*>0.05) (Table 7).

Table 7. Comparison of the antecurvation-recurvation angles of the operated and healthy legs.

Groups	Antecurvation-recurvation angle		
	Operated leg	Healthy leg	*P* value
Intramedullary nail	3.4±2.1	0.44±1.2	*0.022*
Plate	1.77±2.1	0.59±1.3	*0.000*

In the plate fixation group, no significant difference was found in limb length between the operated and intact extremities (p=0.465). In the intramedullary nailing group, however, the measurements of the operated extremity were significantly greater than those of the intact extremity (*p*=0.017). No significant difference in terms of limb length was observed between the two patient groups (*p*>0.05).

Additionally, in both groups, no significant difference was found in terms of rotation between the operated and intact extremities (Plate: *p*=0.340, IMN: *p*=0.535). When comparing the two groups, there was also no significant difference in rotation (*p*>0.05).

4. Discussion

Orthopedic surgeons are faced with a challenge when it comes to managing extra-articular tibial fractures, particularly when deciding on surgical treatment. There are several recognized alternatives for management, including external fixation, open reduction and plate, IMN, and minimally invasive plate osteosynthesis (MIPO). These days, MIPO and IMN are regarded as the cornerstones of tibial shaft fracture care. In patients with extra-articular tibial fractures, in this study, clinical and radiologic outcomes and complications between these two approaches were compared. Complete recovery was achieved in all patients in both groups. There was no statistically significant clinical difference between the two groups. However, the weight-bearing time in the plate fixation group was significantly longer than in the intramedullary nailing group. Similarly, the radiological healing times were significantly longer in the plate fixation group compared to the intramedullary nailing group. No significant differences were found between the two groups regarding varus-valgus angulation, antecurvation-recurvation, and rotation. While no significant difference in limb length was observed between the two groups, a significant difference was noted between the operated and unoperated extremities in the intramedullary nailing group.

A significant constraint of IMN is its challenging nature in achieving and preserving sufficient reduction. Nails could be used to obtain a satisfactory alignment in the center of the tibia shaft, although this is a short segment [10]. The IMN is unable to make contact with the tibial cortex in the zones where the proximal or distal portion of the shaft is heterogeneous. In such instances, the locking nails at both ends would be the only thing needed to keep the reduction in place. As a result, the torsional stability of the IMN fixation is low and rather weak [11]. There have been higher angular malalignment using IMN versus plates in previous trials of proximal or distal tibia fractures [12,13] takes a highly skilled surgeon to achieve the correct alignment with a nail [14]. The quality and stability of reduction may be improved by using percutaneous reduction procedures, poller screws, and distal multi-axial locking screws. Nevertheless, these operations result in increased blood loss, increased fluoroscopy times, and prolonged surgical times [15]. Although reamed IMN may result in delayed healing due to damage to the medullary blood flow, it may also offer improved stability [16,17]. Ankle pain originating from an anatomical region close to the ankle has also associated with malalignment. Ankle discomfort and degenerative alterations have been linked to distal tibia malalignment [18]. For these reasons, MIPO may be chosen for the treatment of tibia shaft fractures where reduction is challenging to achieve to provide improved alignment and stability. Our findings corroborate this suggestion by demonstrating that the clinical and functional outcomes of the two methods are comparable.

Bombacı et al. compared the outcomes of plate fixation and intramedullary nailing in 44 patients with 45 tibial diaphysis fractures. In the study, 26 tibiae were treated with intramedullary nailing and 19 with plate fixation, with the average healing time being 3.5 months for the plate fixation group and 5 months for the intramedullary nailing group. The researchers reported no limb shortening in any of the patients treated with plates, while two patients in the intramedullary nailing group experienced limb shortening of 2 cm or more. The authors concluded that for non-multifragmentary tibial fractures, plate-screw osteosynthesis is preferable, whereas intramedullary nailing, which disrupts periosteal circulation less, may be recommended for multifragmentary fractures [19]. Fernandes et al. studied 45 tibial fractures, applying plate-screw osteosynthesis in 22 cases and intramedullary nailing in 23 cases. They found that plate-screw osteosynthesis led to an average of 4.32 weeks earlier healing in multifragmentary tibial fractures, but there was no significant functional difference between the two techniques [20].

Johner and Wruhs [9] classified outcomes into excellent, good, fair, and poor categories according to criteria such as nonunion, osteomyelitis, amputation, deformity, joint motion restriction, pain, walking function and activity level. Ekeland et al. reported a 93% excellent and good outcome rate in 45 patients who underwent locked intramedullary nailing, with remaining 7% classified as fair or poor [21]. Similarly, Alho et al. reported 81% excellent and good, 11% fair, and 8% poor results [22]. In our study, when evaluating the range of motion (ROM) of the knee, ankle, and subtalar joints, we found that all patients had complete subtalar joint and ankle mobility. Two patients demonstrated 110° of flexion in their knee movements. Additionally, 5 patients reported occasional knee pain, while 4 patients experienced moderate knee pain. When assessed according to Johner and Wruhs' criteria, 17 patients (68%) were classified as having excellent outcomes, 4 patients (16%) as good, and 4 patients (16%) as fair. Our results are comparable with the literature.

Our study has several limitations. Being a retrospective study, relatively small sample size and being a single-center study are noteworthy constraints. Additionally, we could have provided a more detailed discussion of the comorbidities that may affect fracture healing. However, our follow-up period is considered above average compared to studies in the literature. Another strength in our study is the examination of functional results both in the knee and ankle. As for future research, conducting a multi-center study with a larger cohort would be necessary to clarify these topics and provide more robust data.

4.1. Conclusions

In summary, both IMN and MIPO are safe and efficient treatments for tibia shaft fractures, and our findings support that the clinical and functional outcomes of both treatments are comparable. These findings suggest that MIPO can be favored instead of IMN for tibial shaft fractures. Further research is needed to fully comprehend the advantages and disadvantages of various tibial shaft fracture treatment options.

Acknowledgement: *Since this study was derived from my medical residency thesis, I would like to extend my gratitude to everyone who contributed to my education throughout my career.*

Funding: *The authors received no financial support for the research, authorship, and/or publication of this article.*

Conflict of Interest: *The authors declared no conflict of interest.*

Ethical Statement: *The study was approved by Hamidiye Şişli Etfal Training and Research Hospital (No: E-79341859-000-278490817).*

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