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Review article

Open Tibial Shaft Fracture Fixation Strategies: Intramedullary Nailing, External Fixation and Plating

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Abstract

Tibial shaft fractures are among the most prevalent orthopedic injuries, representing about 2% of all fractures in adults and 37% of long bone fractures. These injuries occur frequently in both high-energy trauma scenarios and low-energy falls, with significant variations in treatment based on fracture severity and patient age. The Gustilo-Anderson classification guides treatment based on fracture severity. Conservative treatment with casting is effective for stable fractures but carries risks like delayed union and malunion. Surgical management, including external fixation, intramedullary nailing (IMN), and plating, is essential for displaced or complex fractures. External fixation offers rapid stabilization but has higher infection risks. IMN, preferred for its stability and minimal soft tissue damage, is effective for diaphyseal and open fractures. Plating is less common but useful for specific fracture patterns. Management of tibial shaft fractures requires a tailored approach considering fracture type, patient health, and potential complications. Both conservative and surgical methods have specific advantages and limitations. Further studies are needed to optimize treatment strategies and improve patient recovery.

Keywords: Tibial shaft fractures, Open tibial fractures, External fixation; Intramedullary nailing; Percutaneous locking plate

Tibial shaft fractures – An overview

Tibial shaft fractures are among the most common long bone fractures, often resulting from high-energy injuries such as motor vehicle accidents, which account for approximately 43% of cases. The overall incidence is estimated to be between 17 and 21 per 100,000 individuals, with open tibial fractures account for approximately 25% of all leg shaft fractures. These fractures are particularly concerning due to their potential to cause long-term complications, prolonged hospital stays, and increased healthcare costs. High-energy trauma, such as falls from significant heights and motor vehicle accidents are the most common causes of tibial shaft fractures. Research indicates a bimodal distribution in the presentation of these fractures, where younger individuals typically experience them following high-energy events. At the same time, older adults often sustain fractures from lower-energy incidents, such as ground-level falls. The added complexity of soft tissue involvement makes it especially difficult to treat open tibial shaft fractures. Open tibial shaft fractures are complicated because of the added complexity of soft tissue involvement. Effective fracture fixation strategies are crucial to reduce the risk of complications such as malunion, nonunion, infection or other postoperative complications [1,2,3].

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Classification of tibial shaft fractures

The severity of an open fracture significantly affects both the treatment approach and patient outcomes. This has led to the establishment of grading systems that systematically categorize fractures with similar characteristics. The Gustilo-Anderson classification system, known for its simplicity and practicality, has been widely utilized for all types of open fractures for the last 36 years, even though it was initially developed specifically for tibial fractures (Table 1) [4,5].

Table 1. Gustilo-Anderson classification for open tibia fractures

Type	Description	Wound Characteristics
Type I	Limited periosteal stripping	Clean wound less than 1 cm
Type II	Mild to moderate periosteal stripping	Wound greater than 1 cm in length
Type IIIA	Significant soft tissue injury, significant periosteal stripping	Wound greater than 1 cm in length, no flap required
Type IIIB	Significant periosteal stripping and soft tissue injury	Flap required due to inadequate soft tissue coverage
Type IIIC	Significant soft tissue injury with a vascular injury	Vascular injury requiring repair

Etiology

High-energy traumas, particularly motor vehicle collisions, are the predominant cause of proximal tibial fractures in men. In contrast, most fractures in women result from low-energy mechanisms, such as falls during walking or cycling. Typically, low-energy injuries result in unilateral depression-type fractures, whereas high-energy injuries can lead to comminuted fractures that involve significant damage to bone, soft tissue, and neurovascular structures. Fractures of the tibial head can occur due to forces acting from multiple directions, including medial, lateral, or axial forces. Medial forces, often referred to as valgus forces, are commonly associated with “bumper fractures,” which occur in pedestrian accidents involving vehicles. More intricate injury mechanisms may involve a combination of axial forces along with varus or valgus forces. In many cases, both shearing and compressive forces affect the tibial plateau through the femoral condyle, impacting it from either the medial or lateral sides [6].

Conservative treatments

Stable, non-displaced fractures of the tibial shaft can be effectively treated with conservative methods, typically involving the application of a cast. This conservative approach usually involves wearing a thigh plaster cast for about 4 weeks, after which a functional brace may be utilized for an additional 8 to 12 weeks. There is no clear consensus on the acceptable limits for articular step-off and gaps; however, discrepancies of less than 2 mm and gaps of under 5 mm are generally regarded as tolerable [6,7].

Regular radiographic monitoring is essential, typically performed every 2 weeks. The duration of treatment depends on the fracture type, with rotational fractures generally requiring 8-10 weeks and transverse fractures needing at least 12 weeks of immobilization. However, the extended period of cast treatment increases the risk of deep venous thrombosis, compartment syndrome, soft tissue injury, and chronic regional pain syndrome. Casting for tibial fractures is associated with the lowest incidence of infection; however, it has a higher prevalence of delayed union, nonunion, and malunion. Furthermore, diagnosing soft tissue injuries and compartment syndrome is more difficult when the fracture is managed with a cast [7].

Principles of surgical management

Historically, open fractures have been associated with high mortality rates and severe outcomes. However, advancements in modern surgical techniques have dramatically improved the prognosis for these injuries. Standard principles in managing open fractures include:

- Initial assessment and resuscitation
- Antibiotic and tetanus prophylaxis
- Surgical debridement and copious irrigation
- Fracture stabilization
- Soft tissue closure
- Thorough rehabilitation
- Adequate follow-up

Additionally, surgeons can utilize adjunct therapies such as local antibiotic therapy, vacuum-assisted therapy, free tissue transfer, or bone grafting. The primary goals are to prevent infection, promote healing, and restore function. However, if necessary, a delayed primary amputation should be considered within 72 hours of the injury [4].

Surgical treatments

Surgery may be indicated for open fractures, fractures that fail to heal with non-surgical methods, fractures with displacement, or those with multiple fragments. Operative treatment using standardized protocols is frequently employed. Prolonged casting can lead to significant discomfort for patients and may present challenges in managing the fracture effectively. Immediate surgical intervention is necessary in cases such as open fractures, compartment syndrome, concurrent nerve or vessel injuries, or when multiple injuries are present. Definitive skeletal stabilization should be performed as soon as possible after debridement; if this is not feasible, temporary external fixation is recommended. Surgical techniques for bone fixation include intramedullary nailing (IMN), external fixation, and plate-and-screw fixation. The choice of technique should be based on the fracture's location, type, and the extent of soft tissue damage [4,7,8].

External fixation

External fixation involves realigning the fractured bone fragments, typically through closed reduction, and/or transverse insertion of ~~metal~~ screws and pins into the bone segments above and below the fracture site. These screws/pins are then attached to a stabilizing bar structure that remains outside the skin. This technique allows the bones to be held in the correct position to facilitate healing [8].

Beltsios et al. conducted a retrospective study to assess the effectiveness of unilateral external fixators for treating open tibial fractures, severe soft tissue injuries, threatened compartment syndrome, and multiple injuries. The study included 223 patients, with 139 having Gustilo Type III open fractures. The average time to fracture union was 25 weeks. Complications included 18 nonunions, 21 delayed unions, 4 malunions, 58 pin site infections, and 3 cases of osteomyelitis. The authors concluded that advancements in external fixator technology make them a viable option for severe tibial shaft fractures, especially with significant soft tissue damage or impending compartment syndrome [9].

Indications

External fixation is recommended as the primary method of stabilization for patients with multiple traumas, severe soft tissue injuries near joints, or those who are generally not suitable for surgical intervention. There are no contraindications for using external fixation in cases of tibial shaft fractures. According to the damage control principle, initial external fixation is the preferred approach for managing multiple trauma patients. Additionally, patients at higher risk include those with thoracic injuries, craniocervical trauma, hypothermia, or coagulopathy. The risk of infection does not increase if a procedural change is made within 5 to 10 days. Primary external fixation is also beneficial for severe soft tissue injuries without fractures, as it provides necessary immobilization. Furthermore, external fixators continue to be employed for the definitive treatment of juvenile tibial shaft fractures [7].

Outcomes

While external fixators allow for quick fracture stabilization and minimize further soft tissue damage, when used as the definitive treatment they frequently lead to complications such as pin loosening, pin tract infections, and malunion. Infection of the tissue around the pin sites is a common complication of external fixation, which can be mitigated by using proper pin insertion technique and meticulous postoperative pin site care. Although these infections are typically localized and rarely progress to osteomyelitis, intramedullary nails should be used judiciously if an infection develops at the pin site [7,8].

Intramedullary nailing (IMN)

IMN is currently the most widely used method for treating tibial fractures, although there are specific indications and contraindications. The procedure involves the insertion of a specialized metal rod (typically made of titanium) into the tibial canal after a closed or open reduction of the bone fragments. The intramedullary rod is secured to the bone at both ends, ensuring that the nail and bone remain properly aligned throughout the healing process. The key advantages of IMN include biomechanical stability, a minimally invasive approach that avoids direct exposure to the fracture site, preservation of the periosteal blood supply, limited soft tissue damage, and the ability to control alignment, rotation, and translation. Evidence strongly supports the use of IMN as the preferred implant for diaphyseal tibial fractures. Additionally, substantial evidence indicates that intramedullary nails provide advantages over external fixation for open fractures, provided that wound closure can be achieved shortly after initial stabilization [1,7,8].

Indications

IMN is indicated for open and closed isolated tibia shaft fractures, extraarticular distal tibial fractures, oblique, transverse, segmental, torsion, debris fractures, and open fractures with bone loss. It is also used for segmental, comminuted, bilateral tibia fractures, and ipsilateral limb injuries. IMN is contraindicated in cases of severe soft tissue injuries, multiple trauma patients, thoracic trauma, infection, non-union, or children with joint growth. In open tibia fractures, IMN can be effective within 24 hours. It is also contraindicated in children with open physis, where, external fixation is preferred. Recent advancements in nail design and reduction techniques have expanded IMN indications to include proximal and distal third tibial fractures [7,8].

Outcomes

IMN is considered a standard treatment for diaphyseal fractures of long bones, despite risks such as endosteal necrosis and systemic fat embolism. It supports biological osteosynthesis by preserving the fracture hematoma. The use of angular stable locking screws enhances control over rotation, length, and alignment, expanding its indications. However, there is an ongoing debate about whether IMN should be performed with reaming or unreamed, and whether to use locking screws [7].

Intramedullary reaming deposits debris at the fracture site, acting as an autologous bone graft and enhancing cortical contact for better stability. However, it can disrupt the endosteal blood supply, which is crucial for healing. In contrast, unreamed IMN preserves this blood supply, leading to faster healing and a lower risk of infection. Due to the negative effects of reaming on the endosteal blood supply, unreamed IMN has become widely used for both open and closed tibial shaft fractures. This technique is preferred for its ability to maintain the endosteal blood supply, thus reducing complications associated with healing. Consequently, unreamed IMN has seen extensive clinical use for both open and closed tibial shaft fractures [7].

Tielinen et al. conducted a study to evaluate the outcomes of acute surgical debridement, unreamed IMN, and muscle flap reconstruction for severe Gustilo type IIIB to IIIC open tibial shaft fractures. Over a 10-year period, 19 patients with extensive soft tissue injury and suitable for nailing were treated. Follow-up assessments showed all fractures healed without infection complications, with a mean union time of 8 months. A total of nine patients experienced delayed healing, requiring additional interventions such as exchange nailing or bone grafting. The overall functional outcome was good in 18 of 19 patients despite some tibial shortening and external rotation in a few cases. The study concluded that acute surgical debridement, unreamed IMN, and muscle flap reconstruction are safe and effective for treating severe open tibial shaft fractures [10].

Percutaneous locking plate

Plating, also known as plate osteosynthesis, is a less common method for fixing open tibial shaft fractures. The process begins with repositioning the fractured bone fragments through either closed or open reduction techniques. Initially, an incision is then made on the skin to access the bone, and plates are applied through this incision. These plates are secured to the bone with screws, which hold the bone segments together and promote healing [1,8].

Indications

Traditionally, conventional plate osteosynthesis was the preferred method for tibial shaft fractures without soft tissue injury. However, it has recently been replaced by IMN with locking screws. Plate osteosynthesis is still employed for proximal and distal tibia fractures when IMN is insufficient. Poor skin and soft tissue conditions, along with compromised blood flow, can complicate surgical decisions and lead to numerous complications. In elderly patients with osteoporosis and comminuted fractures, achieving stable fixation is challenging due to the reduced bone volume and quality. In such cases, a locking plate combined with pro-fibula screws may be used for tibial fixation [7,8].

Outcomes

Potential postoperative complications associated with plate osteosynthesis include non-union, delayed union, and wound infection. Studies comparing the outcomes of PLP and IMN are limited and inconsistent [8]. He et al. conducted a meta-analysis comparing minimally invasive percutaneous plates and interlocking

IMN for tibial shaft fractures. The study found that percutaneous plates led to faster healing and fewer postoperative complications, such as delayed union and pain. However, there were no significant differences in functional recovery, reoperation rates, or other complications between the two methods. Further high-quality, multicenter randomized controlled trials are needed to better compare these methods and optimize patient management [11].

Comparative studies

Table 2 provides a comparative summary of studies evaluating IMN, external fixation, and plating techniques for the treatment of tibial shaft fractures.

Table 2: Comparative analysis of fixation methods for tibial shaft fractures—IMN, external fixation, and plating

IMN vs external fixation					
Study	**Patients**	**Fracture Type**	**Result (IMN vs EF)**		**Conclusion**
Mohseni et al. (2011) [12]	n=50	Gustilo type IIIA & IIIB	Post-operative infection	16 vs. 32%; p=0.19	IMN is associated with fewer infections and healing problems, and faster recovery time compared to EF
			Soft tissue injury	8 vs. 12%; p=0.50	
			Malunion	0 vs. 24%; p=0.02	
			Nonunion	4 vs. 8%; p=0.50	
			Mean ambulation time after the operation	2.92 ± 2.43 vs. 2.68 +/- 2.14; p = 0.71	
Haonga, et al (2020) [13]	n=240	Diaphyseal open tibial	Death or reoperation	18.0 vs. 21.9%; RR=0.83 [95% CI, 0.49 to 1.41]; p = 0.505)	
			Rate of deep infection	No significant difference	IMN is associated with a lower risk of coronal malalignment and better early radiographic healing compared to EF. No significant difference in deep infection rates or overall primary outcome events.
			Coronal malalignment (Lower risk with IMN)	RR=0.11; p=0.01	
			Sagittal malalignment (Lower risk with IMN)	RR=0.17; p=0.065	
			Quality of life (EQ-5D)	Higher with IMN at 6 weeks, no difference at 1 year	
			Radiographic healing (mRUST)	Better with IMN at Better at 6 weeks, 12 weeks, and 1 year	
Kisitu et al. (2022) [14]	n=55	Gustilo-Anderson type II & IIIA	Functional outcome (FIX-IT score)	1.0-point higher for IMN	IMN provides marginal improvements in functional outcomes and significantly reduces malunion and superficial infection compared to EF
			Health-related quality of life (EQ-5D-3L & EQ-VAS)	Similar results for both groups	
			Radiographic healing (RUST)	No difference between both groups	
			Malunion rate	22.1% (95% CrI, –42.6% to 1.7%) lower for IMN	
			Superficial infection	20.8% (95% CrI, –44.0% to 2.9%) lower for IMN	
IMN vs plating					
			Results (IMN vs plating)		
Vallier et al. (2011) [15]	n=104	Extra-articular distal tibia shaft fractures	Deep infection	5.8% in both groups	Malalignment was more common with nails, especially in open fractures. Nonunion and infection rates were similar between the two methods.
			Nonunion	7.1% vs. 4.2%; p=0.25	
			Trend: Higher nonunion in patients with distal fibula fixation	12% vs. 4.1%, p = 0.09	
			Primary angular malalignment of ≥5°	23% vs. 8.3%; p= 0.02	
			Secondary procedures	14 procedures (IMN) vs. 15 procedures (Plating)	
Vallier et al. (2008) [16]	n=111	Extra-articular distal tibia fractures (4 to 11 cm proximal to the plafond)	Osteomyelitis	5.3% vs. 2.7%; p=0.10	Plating is associated with fewer cases of malalignment and delayed union compared to IMN. Similar rates of infection and hardware removal.
			Delayed union or nonunion	12 vs. 2.7%; p=0.10<	
			Angular malalignment ≥5 degrees	29 vs. 5.4%; p=0.003	
			Painful hardware removal	7.9 vs 5.4%	

Study	Patients	Fracture type	Result (IMN vs. EF)		Conclusion
Kang et al. (2021) [17]	n=73	Closed extra-articular tibial shaft fractures (AO/OTA type 42)	Bone Healing	1 case of nonunion in each group (p>0.05)	IMN and MIPO showed no significant differences in radiological and clinical outcomes, both being equally effective for treating tibial shaft fractures.
			Callus Formation	Mean 12 weeks in both groups (p>0.05)	
			Operative Time	No significant difference (p>0.05)	
			Hospital Stay	No significant difference (p>0.05)	
			Complications	No significant difference (p>0.05)	
			Functional Evaluation	No significant difference (p>0.05)	
Plating vs External fixation					
			Results (Plating vs EF)		
Krupp et al., 2009 [18]	n=58	Schatzker V/VI or AO/OTA type 41C	Time to Union	5.9 months vs. 7.4 months	Locked plating showed faster union, fewer cases of articular malunion, less knee stiffness, and lower overall complication rates compared to external fixation. External fixation is used as a temporary measure until definitive fixation with plating can be performed.
			Articular Malunion	7% vs. 40%; p=0.003	
			Knee Stiffness:	4% vs. 13%	
			Overall Complications	27% vs. 48%	
			Schatzker VI Subgroup complications	93% vs. 83%	
Comparison of intramedullary nail, plate, and external fixation in the treatment of distal tibia nonunions					
Ebraheim et al., 2017 [19]	n=33	AO/OTA 43A & distal third 42A-C nonunions	Mean Time to Union (without revision fixation)	IMN: 12 weeks, PO: 27 weeks, EF: 13 weeks (p = 0.202)	Time to union was notably shorter when no revision fixation was required. IMN and PO were effective fixation methods, achieving significantly faster union times compared to EF. The time to union was further prolonged with a change in fixation method rather than an exchange of the same method, especially in cases with deep infections.
			Mean Time to Union (with revision fixation)	IMN: 17 weeks, PO: 21 weeks, EF: 66 weeks (p = 0.009)	
			Weeks to the union from nonunion diagnosis (all 29 healed nonunions)	IMN: 14 weeks, PO: 23 weeks, EF: 72 weeks (p = 0.009)	
			Revision Fail Rates	IMN: 0%, PO: 25%, EF: 71%	
			Time to Union (revision method change vs. the same method)	51 weeks vs 18 weeks (p = 0.030)	

IMN: Intramedullary Nailing; EF: External Fixation; PO: Plate Osteosynthesis; VLP: Volar Locking Plate; MIPO: Minimally Invasive Plate Osteosynthesis; mRUST: Modified Radiographic Union Score for Tibia; RUST: Radiographic Union Score for Tibia; EQ-5D: EuroQoL Five-Dimensional Scale; EQ-VAS: EuroQoL Visual Analog Scale; FIX-IT: Functional Index for Extremity Injuries; DASH: Disabilities of the Arm, Shoulder, and Hand; VAS: Visual Analog Scale; AO/OTA: Arbeitsgemeinschaft für Osteosynthesefragen / Orthopaedic Trauma Association
CrI: Credible Interval; CI: Confidence Interval.

Conclusion

The management of tibial shaft fractures, especially open fractures, requires careful assessment of various fixation strategies: IMN, external fixation, and plating. Each method has unique advantages and considerations based on fracture severity and soft tissue involvement. IMN is often preferred for its biomechanical stability and minimal soft tissue disruption. It allows for early fracture stabilization and is particularly effective for diaphyseal fractures and select open fractures where timely wound closure is possible. External fixation provides rapid stabilization, which is essential for severe soft tissue injuries or when immediate definitive fixation is not feasible. However, it is associated with a higher risk of complications, including pin tract infections and malunion. Plating, although rarely used for tibial shaft fractures, is useful in cases that require additional fixation strength, especially for specific fracture patterns or when IMN is unsuitable due to soft tissue concerns. The choice of fixation method ultimately depends on individual patient factors, fracture characteristics, and the surgeon's expertise. The goal is to minimize complications such as nonunion, malunion, and infection. Further studies and advancements in techniques will continue to improve treatment approaches for these complex injuries.

Article information

Conflicts of interest

The authors have no conflict of interest to declare.

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Data availability

Data of this study are available from the author/s upon reasonable request.

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