Chapter

Far Proximal and Far Distal Tibial Fractures: Management with Intramedullary Nails

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Abstract

Operative treatment of tibial fractures located at the proximal metaphyseal-epiphyseal and distal metaphyseal-epiphyseal areas, including those with articular extensions, is a technical challenge. Common methods for surgical management include plates (locking and nonlocking), external fixation devices, and intramedullary nails. All these methods have shown satisfactory results in terms of quality of reduction and clinical and radiological outcomes. The authors present some technical methods and strategies that have been useful for the surgical approach, reduction, and fixation of these lesions with the use of locked nails.

Keywords: proximal, distal tibial fractures

1. Introduction

Tibial fractures located in the proximal and distal meta-epiphyseal areas pose a technical challenge for surgical management [1, 2]. A very proximal or distal fracture fragment, which may include intraarticular involvement, is difficult for proper reduction and alignment with the diaphysis [3], and at times, there is little bone stock available for solid fixation, either with plates or with nails. Aside from this, the soft tissue envelope is tenuous – especially at the distal tibia – and may result in damage due to trauma [4]. The evaluation of the quality of soft tissues is key when selecting any method for surgical treatment. Common surgical techniques include plates (either locking or nonlocking), locked intramedullary nails, and external fixators [5, 6]. These methods have shown good results in terms of quality of reduction and functional outcomes.

Intramedullary nailing (extreme nailing) is a competent method for the management of these difficult injuries [1]. Careful planning and surgical technique are essential for good reduction and stable fixation [7]. The authors present some strategies, technical considerations, and methods that have been useful for the achievement of these goals.

2. General preparation and positioning

Positioning of the patient is the first and at the same time critical aspect to be considered that influences the final surgical result. For conventional, transpatellar or parapatellar intramedullary nailing, the senior author (LB) uses a thigh holder

Figure 1.
The position for conventional transpatellar approach. The use of a thigh holder allows for knee flexion greater than 90°, facilitating approach, reduction, and nail insertion in most tibial fractures. For more proximal injuries, the proximal fragment can be pushed manually in further flexion for proper alignment and reduction.

Figure 2.
Intraoperative photography showing the different elements necessary for proper suprapatellar insertion technique: special instrumentation and continuous verification of the procedure by fluoroscopy.

that is commonly utilized for arthroscopic procedures. It is located at the level of the popliteal space or just proximal to it, allowing a knee flexion of 90° or more, and with the foot barely touching the operating table (**Figure 1**). This facilitates exposure of the entry point and an easy insertion of the intramedullary guide and the nail. The transpatellar approach allows direct visualization and palpation of the correct entry point, so intraoperative X-rays are regularly not needed for this step [8, 9].

The more novel suprapatellar approach is done with the knee in a semi-extended position, for which a pad or small roller is located at the level of the popliteal space. This technique requires special instrumentation (**Figure 2**). Aside from this, clear AP and lateral X-ray views of the proper entry point are important [10]. Although there is not a clearly proven advantage over the traditional transpatellar approach, the simplicity of the leg positioning has made it much more popular [11].

3. Intramedullary nailing of far-proximal tibial fractures

Very proximal tibial fractures, which may include a simple articular split or depression fracture of one or both plateaus, are suitable for intramedullary fixation. Planning should consider the energy involved and "personality" of the fracture (open or closed fractures, concomitant injuries, damage to soft tissues, displacement of bone fragments, articular involvement, and quality of bone stock in the proximal fragment) [12].

Roughly, even with modern methods for improving intraoperative reduction, malalignment remains up to 10% of the cases. Three factors should be taken into account to prevent malalignment: first, there is a natural tendency for the proximal fragment to hyperextend as the knee flexes, due to the pull of the patellar tendon. Second, valgus deformity also may occur, usually due to a combination of soft-tissue pull and misplacement of the starting point for nail insertion. The anatomy of the triangular-shaped proximal tibia and diaphysis causes the medullary canal to be aligned in correspondence to a point slightly lateral to the midline of the epiphysis. Third, the nail design, in particular, is the so-called Herzog angle. If this angle is at the level or distal to the fracture, it tends to displace posteriorly the distal fragment.

For most surgeons, the optimal starting point is proximal to the anterior edge of the articular margin and slightly medial to the lateral tibial spine [10].

In conjunction with careful selection of a correct starting point, we utilize three methods to aid in proper reduction and counteract deformity forces: a suprapatellar approach with the leg in a semi-extended position [13], limited open reduction and provisional fixation with one or two one-third 3.5 mm plates [10], and the use of blocking (poller) screws to direct the path of the nail and facilitate proper reduction [14].

- Suprapatellar approach and semi-extended positioning: for this, a regular radiolucent table suffices. A radiolucent pad or roller is held under the knee of the affected extremity with 10 or 20° of knee flexion, which is maintained during the procedure. The semi-extended position allows easy alignment of the proximal fragment with the diaphysis by neutralizing patellar tendon pull. It also results very useful for expeditious reduction and nailing of distal fractures and facilitates intraoperative fluoroscopy (**Figure 2**). As cited before, special instrumentation is required, and careful selection of the entry point and initial trajectory of the guide must be verified [10, 13].

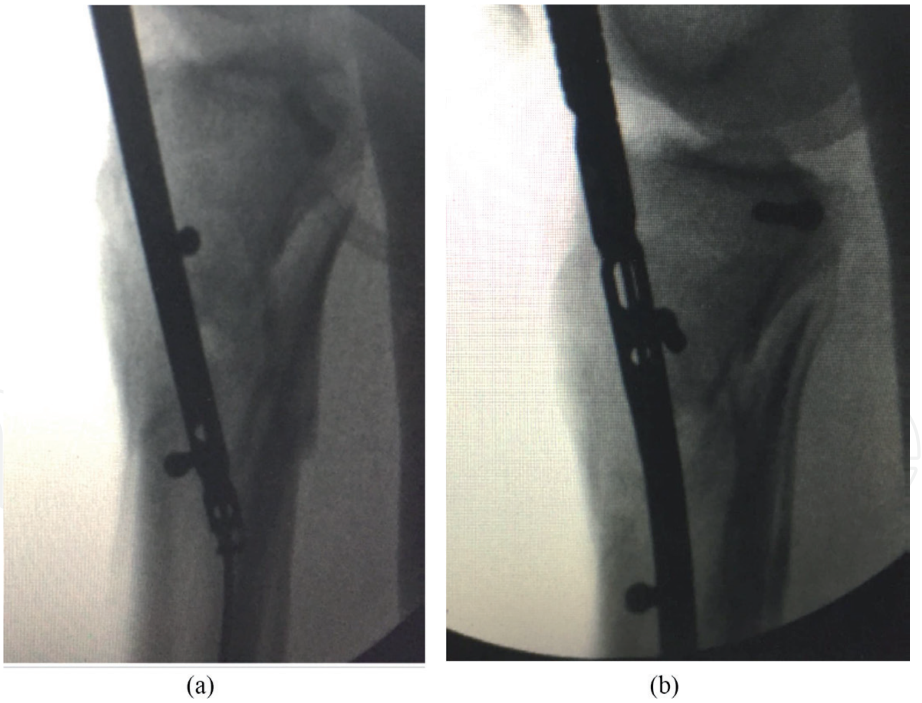
- Direct reduction with small plates: a limited direct approach of the fracture site is performed, and one or two orthogonal 3.5 mm third-tubular plates are inserted to maintain proper fracture reduction and counteracting deforming forces. Most of the times, large cortical fragments are present, proximally and distally, which allow restoration of adequate alignment between the main components of the fracture (**Figure 3**). Variable degrees of knee flexion can be therefore managed without losing reduction. As such, conventional nail insertion through a transpatellar approach can be done with ease. There is no agreement in whether the plate should be removed after nail placement. It has been our experience that plate retaining does not interfere with early weight-bearing nor time to healing. On the other hand, some biomechanical studies advocate the use of three proximal locking screws instead of two for better construct strength, but with the use of reduction plates (and keeping them in place), just two screws are sufficient to maintain reduction till fracture healing (**Figure 4**) [15].

- Blocking or poller screws: one or more percutaneous blocking screws are positioned after initial insertion of the intramedullary guide. As an easy rule of mind, their position should correspond to where the nail "should not go". 3.5 mm cortical screws or the same screws used for interlocking of the nail can be used. In such manner, during nail insertion, the implant itself can act as a reduction tool, on the condition that a correct starting point has been used. We agree that a nail cannot reduce a proximal tibial fracture by itself. Nonetheless, we think that this can be possible, although only in the setting of proper starting point, trajectory in the proximal fragment, and the use of poller screws (**Figure 5a** and **b**) [14].

When intraarticular extension has occurred in the form of simple split fracture of one or both plateaus, or a simple posterolateral depression fracture, direct or

Figure 3.
Direct intraoperative reduction of a proximal comminuted tibial fracture with anterolateral seven-hole 3.5 mm third tubular plate and unicortical screws. This provisional fixation allows maintenance of reduction during reaming and further nail insertion. There is no need for removal of the plate at the completion of the procedure.

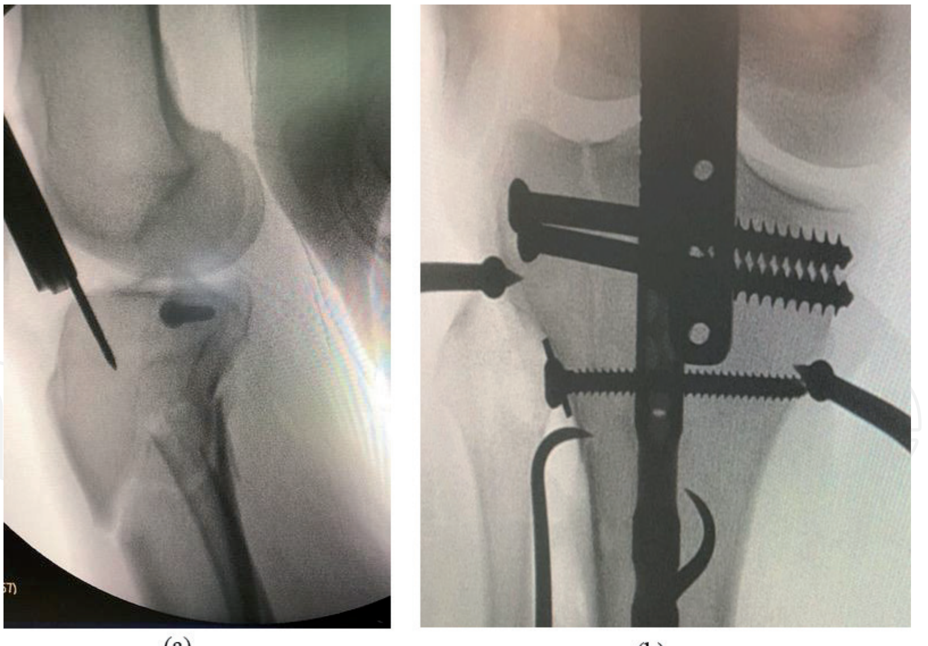
Figure 4.
Proximal tibial fracture in a patient with lupus. Direct reduction and provisional fixation were done with two orthogonal 3.5 mm third tubular plates. Two proximal screws were used for interlocking. Callus and fracture healing maintaining good alignment are seen.



(a) (b)

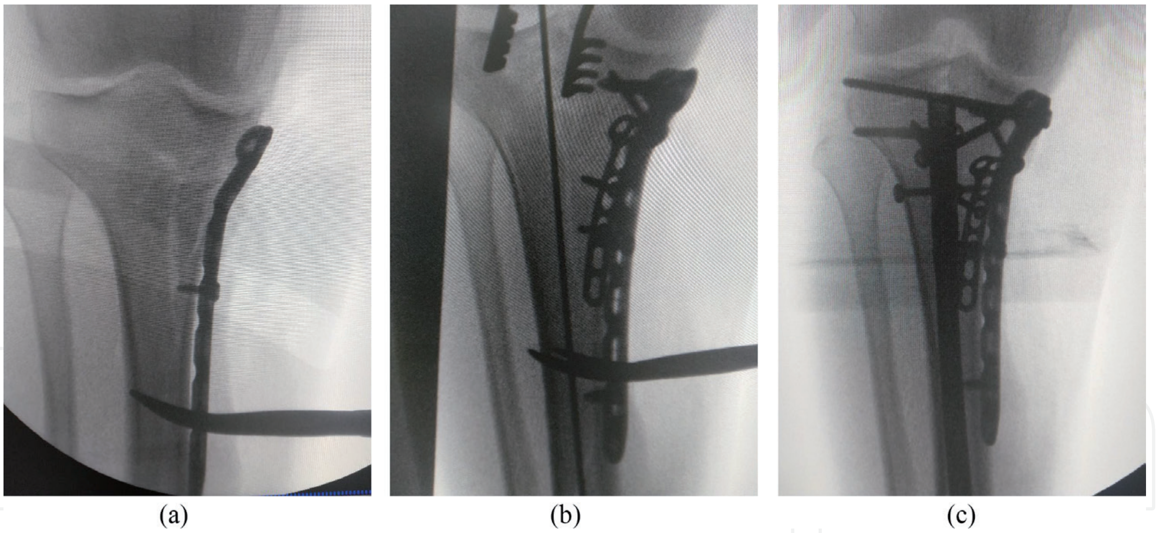
Figure 5.
(a) The use of poller screws to facilitate reduction in a proximal tibial fracture. After a correct starting point has been made, the position of the two poller screws in this case acts as a lever for the nail to be used as a reduction tool. There is a fulcrum in three points of contact: the two poller screws and the posterior cortex of the distal tibial diaphysis. (b) The three contact points direct the nail distally as – at the same time – it works as a reduction tool. The Herzog angle of the nail has to be taken into account for proper positioning of the poller screws.

indirect reduction and fixation with screws are performed [16]. Positioning of screws should be thoroughly planned, in such a way they do not interfere with the entry point nor trajectory of the nail. This implies that coronal screws should be



(a) (b)

Figure 6.
(a) A lateral plateau split component of this proximal tibial fracture has been stabilized with a posteriorly placed coronal 6.5 cancellous screw. There is no interference with the entry point of a suprapatellar approach for nail insertion. (b) Suprapatellar nail insertion has been completed. The lateral plateau split was fixed with three large fragment screws. Two percutaneous clamps are in place to help controlling the articular fracture till final interlocking.



(a) (b) (c)

Figure 7.
(a) Schatzker type VI proximal tibial fracture. Intraoperative management of medial plateau depression and diaphyseal extension with a medial 4.5 mm buttress plate. The unicortical screw secures the plate toward the bone surface, therefore impeding varus deformity at the medial plateau. (b) A second 3.5 mm T-plate was applied as a posteromedial buttress with unicortical screws. Adequate reduction of the proximal tibia is secured in this manner, so a safe conventional transpatellar approach and intramedullary nailing can proceed. (c) After completion of nailing and interlocking, additional fixation of the medial plate is done with screws, engaging the intact lateral plateau.

inserted posteriorly [17]. Transpatellar or suprapatellar approaches are both suitable for this type of injuries (**Figure 6a** and **b**). Articular fractures with diaphyseal extension (Schatzker type VI fractures) might need more complex provisional stabilization in order to maintain continuity between the epiphyseal and diaphyseal components. This can be accomplished with longer unicortical plate applied as buttressing devices (**Figure 7a**–**c**).

4. Intramedullary nailing of far-distal tibial fractures

Distal meta-epiphyseal tibial fractures account for approximately 15% of distal tibial fractures [18]. As for proximal fractures, plate fixation has been also a well-proven method for treatment. However, the tenuous soft tissue envelope poses a significant limitation for open techniques. As such, percutaneous plating has gained popularity, although more comminuted fractures usually require more than one plate to avoid failure and loss of alignment [19].

Intramedullary nailing, in our appreciation, results in a much solid construct and has shown a very low incidence of failure and loss of angular alignment, due to the location in the center of the axis of the tibia. The most common residual deformity after nailing of the distal tibia is in valgus [20]. We have utilized both supra and transpatellar approach, with similar results in terms of final alignment. Although some authors have reported better alignment indexes when using the suprapatellar approach, others have found that good alignment occurs also with the infrapatellar technique [21]. Various reduction techniques can be used for proper intraoperative reduction: percutaneous reduction clamps [22], limited direct open reduction [23], traction by means of a femoral distractor or by the assistant surgeon, and possibly the use of a suprapatellar approach [13]. In any case, during the procedure, insertion of the intramedullary guide should follow the center of the distal fragment in both anteroposterior and lateral fluoroscopy views [21, 24].

We have distinguished three distinct far-distal fracture patterns to be efficiently managed by locked intramedullary nailing:

a. **Simple oblique or spiral fractures**. In these, a low or intermediate degree of energy causes a fracture line that extends from the metaphyseal area of the distal tibia to the epiphysis but without entering the joint surface of the plafond. At times, more than one fracture line is seen. For preoperative planning, we routinely request a CT scan with 3-D reconstructions [25, 26] (**Figure 8**). This is a valuable tool that allows to depict which might be the location and trajectory of percutaneous screws that maintain the epiphyseal bone block as a whole

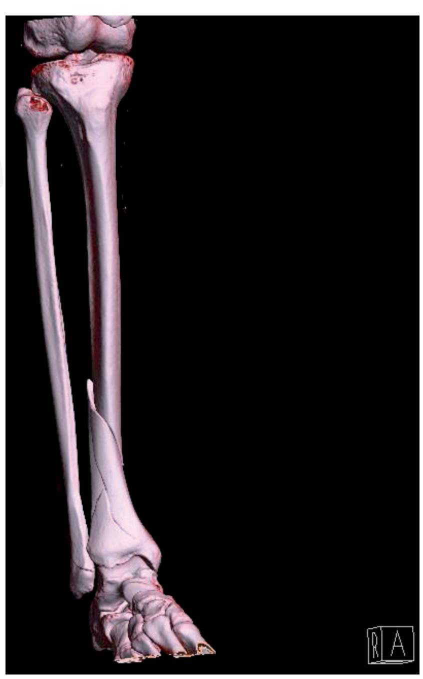


Figure 8.
CT and 3-D reconstruction of a distal tibial fracture with complex spiral epiphyseal extension. The morphology and disposition of the fracture lines can be clearly depicted for proper preoperative planning.

unit, before insertion of the nail. Direct open reduction can be done in selected cases, when anatomical reduction is possible, and the soft tissues are minimally affected by a low-energy fracture pattern [27].

b. **Simple oblique or spiral fractures with articular extension**. These are fractures that include usually a simple split fracture line in the coronal plane or a high medial malleolar fracture, usually both with mild or without displacement. Percutaneous fixation with either 3.5 or 2.7 mm screws prevents articular displacement during final impaction of the nail. At times, the coronal fracture is a split fracture of a large posterior articular fragment in discontinuity with the diaphysis [25, 28]. In these cases, limited open reduction and fixation with a T-shaped 3.5 mm plate are performed, which can be positioned anteriorly or posteriorly prior to nail insertion (**Figure 9a–d**).

c. **Comminuted metaphyseal fractures.** For these, at least two locking screws are needed for stable fixation with a nail. Gorcsyca, in a cadaveric model, showed that two interlocking screws offered similar fixation strength in distal tibial fractures as compared with diaphyseal fractures. In many cases, conventional interlocking screws are enough [24]. Nonetheless, the advent of modern angularly stable locking screws has allowed to improve stability

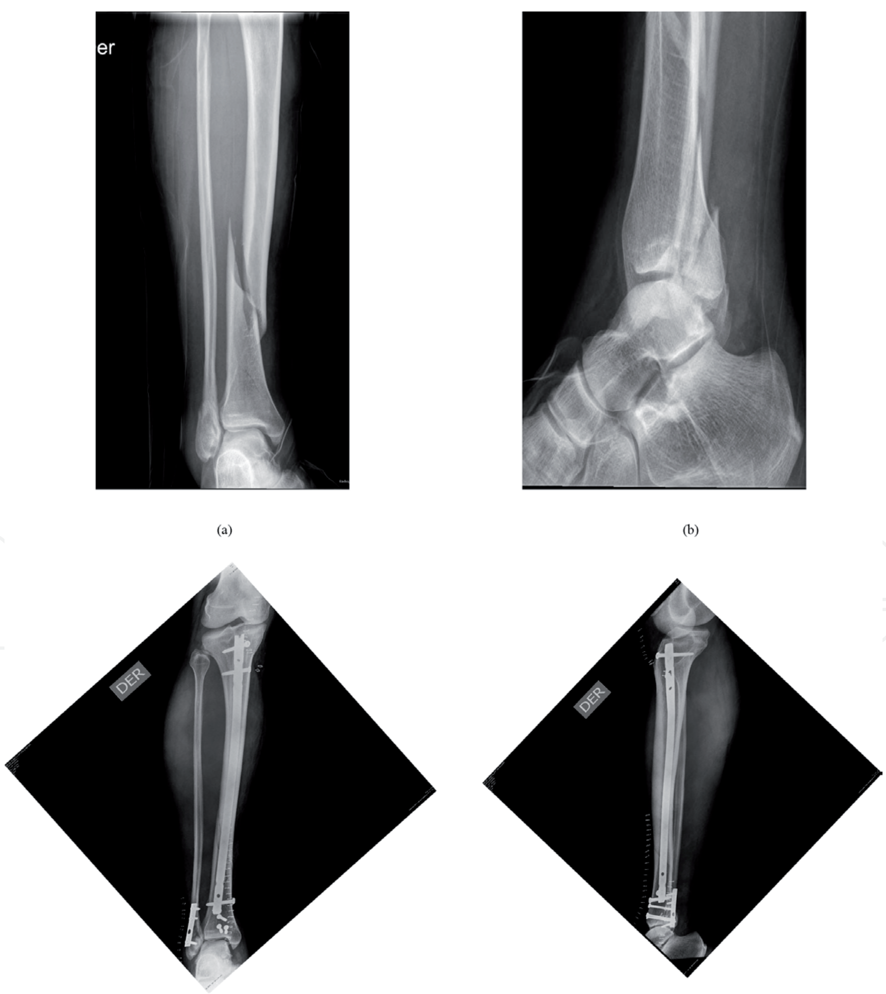


Figure 9.
(a) Anteroposterior radiograph of a distal tibial fracture with a coronal fracture of the posterior malleolus. (b) Lateral view of the lesion, clearly showing the displaced posterior malleolus. (c and d) Anteroposterior and lateral views after direct reduction of the distal fracture with three 4 mm cancellous screws, followed by locked intramedullary nailing and a posterior 3.5 mm third tubular anti-glide plate in the fibula.

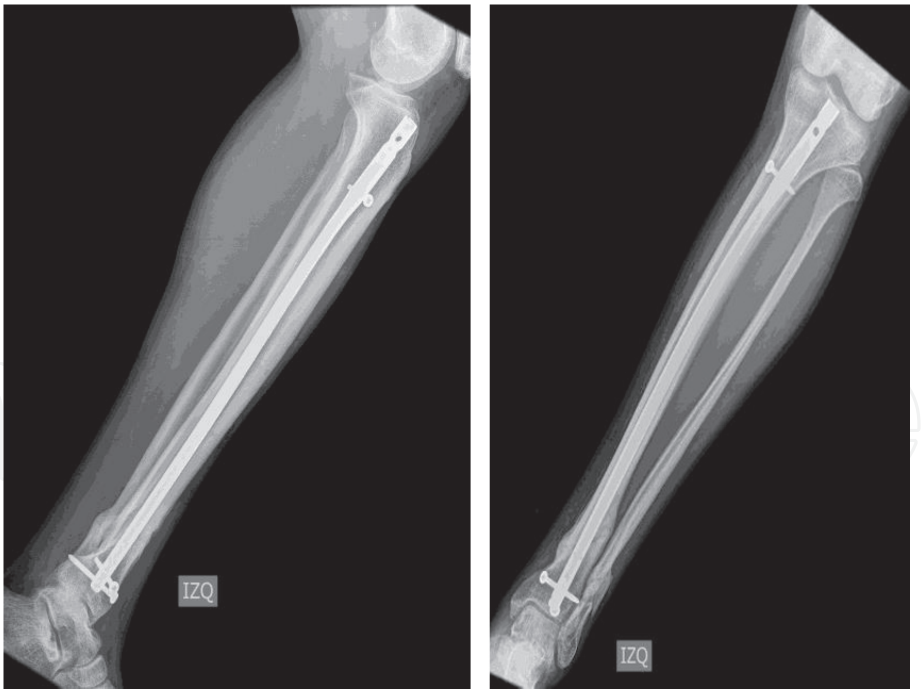


Figure 10.
Follow-up X-rays of a comminuted distal tibial and fibular fracture, treated with nailing and two distal interlocking screws, without fibular fixation. Ankle mortise was stable. Solid tibial fixation alone led to healing without loss of reduction.

even further [29]. Frequently, an associated distal fibular fracture at the same level is present in comminuted distal tibial fractures [28]. Despite that some biomechanical studies have shown that fibular fixation increases the stability of the construct, it is not clear whether this is reflected in better clinical results in long-term follow-up studies [30]. We believe that, if the ankle mortise is not compromised, solid tibial fixation suffices, without the need for osteosynthesis of the fibula (**Figure 10a** and **b**).

5. Fibular fixation in distal tibial fractures

As mentioned before, certain tibial fracture patterns are usually associated with a fractured fibula at the same level. Most of the times, locked intramedullary fixation of the tibia alone is sufficient for proper stability and fracture healing. There is no clear evidence to support the fact that fibular fixation may increase significantly neither the stability of the construct nor the achievement of better clinical outcomes. Moreover, some authors have found that this could increase the rate of nonunion [31]. In a series of 50 patients by Katsenis et al., 31 (62%) had initial fibular fixation with a plate. For the authors, this aided to achieve length, rotation, and alignment of the tibial fracture [32]. We think that there are some fracture patterns that may benefit of fibular fixation, either before or after tibial nailing.

- Comminuted distal tibial fractures and simple fibular fracture: in this case, initial anatomical reduction and fixation of the fibula provide a useful guide for length and rotation of the tibia, which in turn facilitate subsequent tibial nailing (**Figure 11a** and **b**). Care must be taken to correct a tendency for increased varus deformity of the tibial fracture that occurs right after fibular fixation [32].

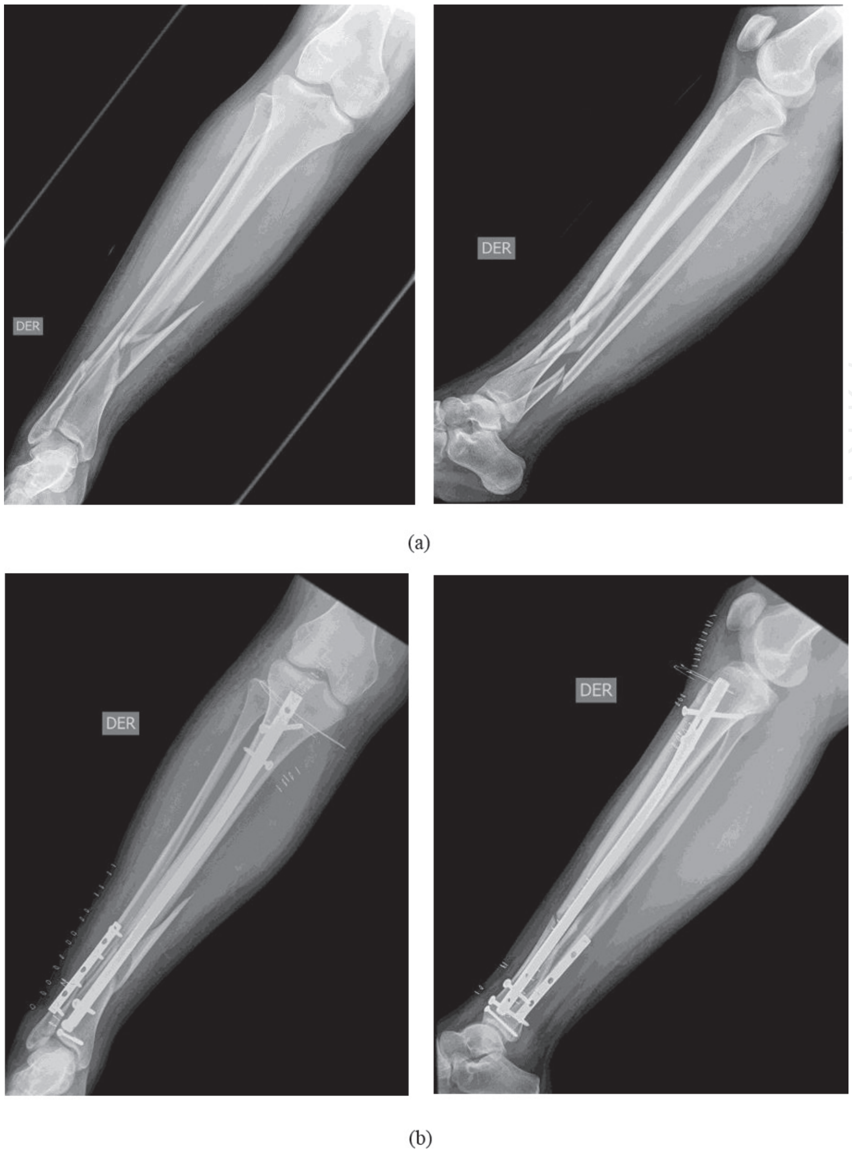
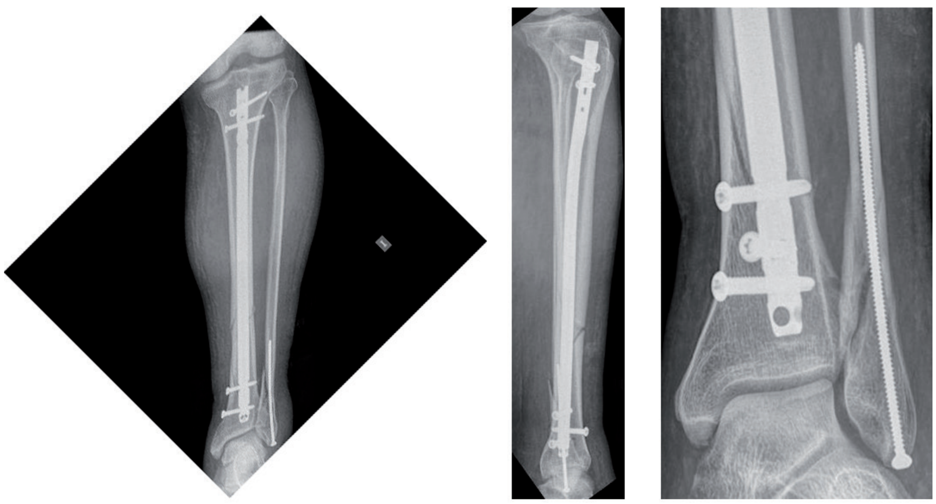


Figure 11.
(a) Comminuted distal-fourth open grade I fracture of the right tibia in a 18-year-old female. A simple fibular fracture is seen at the same level. (b) Open reduction and fixation of the fibular fracture with a 3.5 mm third tubular plate were undertaken first, which help with alignment, length, and rotation of the tibia. This was followed by percutaneous fixation of an undisplaced coronal split fracture at the plafond and locked intramedullary tibial nail via transpatellar approach.

- Comminuted distal tibial and fibular fracture at the same level: as aforementioned, despite the fact that intramedullary fixation and distal locking of the tibia suffices, if the surgeon feels that additional fixation of the fibula – and therefore increasing the stability of the construct – might be a benefit (in particular, when distal interlocking of the tibial nail is precarious), this can be carried out easily [33]. For such fixation, we utilize either an axial intramedullary 3.5 mm screw, that is inserted percutaneously, or a 3.5 mm third-tubular plate [30], after tibial fixation is completed. For axial single-screw fixation, we prefer 90 mm or longer, which is available in a pelvic fracture fixation tray. They are both flexible and very stable, providing a secure fibular fixation (**Figure 12a** and **b**).

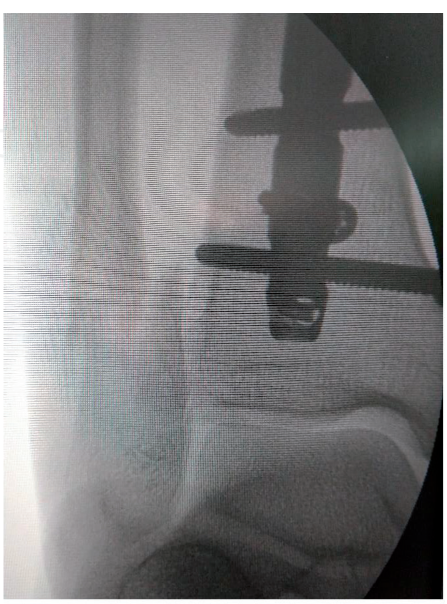
- Compromise of the ankle mortise: in some cases, tibial fractures at the level of the ankle mortise ligaments result in damage to these restraints and consequent instability. If this event is suspected, after tibial fixation, the stability of the mortise should be tested with stress maneuvers, in order to eventually add fixation and correct this condition (**Figure 13a** and **b**).

(a)



(b)

Figure 12.
(a) A 3-D CT reconstruction of a closed distal tibial fracture with extension toward the metaphysis and a comminuted fibular fracture at the same level. (b) Fixation with locked intramedullary nail and three distal interlocking screws. For additional stability, a percutaneous 3.5 mm long screw was used for fibular fixation.



(a)

(b)

Figure 13.
(a) In this case, after nail interlocking of a distal tibial fracture, displacement is seen in the distal fibular diaphysis at the level of the mortise, suggesting ankle instability. (b) Fibular fixation with a 3.5 mm third-tubular plate and two syndesmotic screws inserted with compression of the syndesmosis. Appropriate fibular and syndesmosis reduction were obtained.

6. Conclusions

Proximal and distal metaphyseal and meta-epiphyseal tibial fractures have been traditionally managed with either plating techniques – locking or nonlocking – external fixation devices, limited internal fixation in combination with external fixation, and so on.

The indications for locked intramedullary nails have expanded to include these difficult injuries. Essentials for proper fracture alignment and solid fixation are a correct starting point for reaming and nail insertion, maintenance of sound reduction throughout the procedure, and locking screws to secure the nail. Several techniques have been popularized that aid in proper reduction, including the use of blocking or poller screws, limited open direct fracture reduction, and novel surgical approaches for nail insertion, such as the suprapatellar.

The presence of articular extension of fractures, to either one or both tibial plateaus, or the tibial plafond, can be addressed with nails as well. Usually, percutaneous articular reduction and fixation with screws allow to maintain an articular block as a whole and subsequent safe intramedullary fixation.

Clinical outcomes, which are directly related to good anatomical alignment and articular congruency, have been excellent with the use of these methods, giving support for "extreme nailing" techniques for the management of these complex injuries.

Conflict of interest

The authors declare no conflict of interest.

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