



Nail Osteosynthesis of Proximal Tibia Fractures

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11.1 Indications

Reamed intramedullary nailing of extraarticular metaphyseal fractures of the proximal tibia is an important treatment option to avoid soft tissue complications [1]. Nevertheless, high rates of malunion or nonunion have been reported for this challenging and intensively debated technique [2–6]. Furthermore, nailing of proximal third tibial fractures represents a borderline indication for intramedullary nailing and could result—if not performed properly – in high rates of postoperative misalignment and need for revision surgery [7]. However, the minimal surgical approach and the associated limited soft tissue trauma along with a stable intramedullary fixation also offer great advantages in carefully selected indications.

Based on these aspects, in our opinion intramedullary nailing should be considered an alter-

native treatment option for internal fixation of simple AO/OTA type 41 A2 fractures associated with relevant soft tissue affection.

The results of intramedullary nailing of proximal tibial fracture must be benchmarked to the good outcome of minimally invasive plate fixation [8, 9].

11.2 Surgical Approach

11.2.1 Preoperative Planning, Equipment, and Patient Positioning

Preoperative planning includes biplanar X-rays and CT scans including 3D reconstructions in complex fractures [10] and enables the surgeon to classify the fracture and to apply the correct nail. The aim is to use a nail with both a preferably large diameter and sufficient length. The patient is positioned in supine position on a radiolucent operating table. A tourniquet is not mandatory, but may be placed around the thigh in case relevant bleeding occurs. When using the infrapatellar standard approach, the injured leg is positioned at a minimum of 90° of flexion in the knee joint to achieve optimal exposure of the correct insertion point. A radiolucent carbon triangle may assist in keeping the leg stable in this optimal position.

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11.2.2 Approach and Nail Entry Point

In the standard surgical procedure, intramedullary nailing of tibial fractures is performed through an infrapatellar approach. The correct nail entry point is of significant importance in these fractures. Damage to intraarticular structures and anterior knee pain after nail insertion are reported complications [11]. The so-called *safe zone* for nail insertion is located lateral to the midline of the tibia plateau and medial to the center of the lateral intertubercular tuberosity [12].

Articular damage during tibial nail insertion may result from a lateral parapatellar approach [13]. Especially, the intraarticular portion of the infrapatellar Hoffa fat pad could be damaged during nail insertion after lateral parapatellar incision but not during nail insertion after a medial parapatellar incision. This phenomenon was attributed to significant lateralization of Hoffa's fat pad during knee flexion over 90° which is the best position for tibial nail insertion. Consequently, a medial parapatellar incision seems to be safe and justified for inserting tibia nails without damaging articular structures [13]. However, this medial approach can be problematic in proximal tibial fractures which are accompanied by valgus misalignment and anterior bow deformity in most cases. In those cases, authors recommend using a lateral starting point for nailing to manipulate the proximal fragment slightly against valgus deformation to place the nail more centromedullarily and consecutively to allow for more anatomic reduction [14, 15]. In contrast, overcorrection leading to varus misalignment could be found after choosing a lateral approach for nail insertion and has to be avoided.

In patients with relevant infrapatellar soft tissue lesion, the suprapatellar approach as an alternative permits fixation of the fracture fragments without malalignment and without having to resort to additional fixation tools [16] and is located away from the fracture site, thus avoiding further damage to the soft tissue [17]. However, choosing this approach converts—with respect to the knee joint – a practically extraarticular

approach into an intraarticular approach with all its associated risks with respect to cartilage damage, infection, etc. [13].

11.2.3 Fracture Reduction

Fracture reduction can be achieved indirectly by positioning the patient on the operation table, manually by closed reduction maneuvers, or directly using reduction tools via a so-called mini-open approach directly at the fracture site.

11.2.4 Reaming Process

The correct entry point is achieved by obtaining anterior-posterior and lateral X-ray views. Care has to be taken to sufficiently open the intramedullary cavity; otherwise problems with positioning of the guide wire are probable. A slight and harmonic pre-configuration of the guide wire using flat-nosed pliers is advised in order not to exit the intramedullary cavity dorsally at the fracture site. This has also to be controlled radiographically. Then, sufficient care has to be taken to precisely position the guide wire in the center of the distal tibia [18]. For this purpose, it is helpful to aim at the mid-talar region under fluoroscopic control using anterior-posterior and lateral views. If both the correct entry point and central endpoint of the nail are selected correctly, good axis alignment of the tibial shaft can be expected after successful and X-ray-controlled intramedullary nailing. Sequential reaming under at least 90° of knee flexion is advised using an incremental increase of drill bits with the aim of inserting a nail with an increased diameter of at least 1 mm compared to the final diameter size of the reamer or at least 9 mm in diameter including interlocking screws with a diameter of 5 mm. Since 5 mm interlocking screws significantly increase rotational stability compared to 4 mm interlocking screws, intramedullary nails with a diameter of 8 mm (with 4 mm interlocking screws) are not preferred for stable internal tibial fracture fixation

[19]. In the proximal extraarticular tibial fractures, tibial nails generally should be inserted using three interlocking screws distally as well as proximally. The isthmal region in the intramedullary canal is over-reamed at 1 mm more than the determined, final nail diameter. During the reaming process, it must be ensured that the nail demonstrates good cortical contact and a snug fit and that any fracture gap or dehiscence is avoided [20]. Latest generation tibial nails offer the possibility of interfragmentary compression [21]. Therefore, generally three distal interlocking screws are inserted due to the findings that the greatest increases in torsional and bending stiffness of intramedullary nails are obtained by increasing the number of locking screws [22]. In cases of impaired bone healing, the use of the dynamization mode might be indicated [23]. According to this, one of the proximal locking bolts is placed in the oval hole of the nail offering the option to dynamize the nail secondarily by removing the remaining proximal static locking screws. In addition, the length of the nail must not be selected too short, because the distance between the proximal interlocking screws and the fracture site should be as long as possible. Intraoperatively, tibial torsion has to be assessed macroscopically as well as radiologically.

11.2.5 Additional Fixation Tools

Intramedullary nails allow several hundred thousand cycles of weight bearing. After excessive exposition to shear and bending forces, the implant may fail from fatigue if fracture healing had not occurred in the meanwhile. Therefore, to avoid implant failure, we favor the use of an auxiliary locking plate in cases with short proximal fracture fragments. The additional application of an auxiliary monocortical small fragment plate prior to the reaming process enables fracture reduction and facilitates reaming as well as nail insertion by providing additional stability. Lateral

monocortical auxiliary locking plate fixation increases stability of fracture fragments and therefore represents an effective additional option for proximal tibial fractures with a relevant lack of stability. In general, monocortical plating including 10–14 mm screws is recommended to not disturb the reaming process. For adequate strength of the plate, two to three screws per fracture fragment are mandatory. Earlier observations of our Institute of Biomechanics in trochanteric fractures indicated that interfragmentary rotation and shear forces were significantly lower when utilizing an additional auxiliary locking plate in combination with intramedullary nailing [24, 25]. Also, strains on the nail decreased, and the stiffness of the osteosynthesis increased significantly in combination with auxiliary locking plate fixation [26, 27].

11.3 Subsequent Treatment and Follow-Up

Patients receive physiotherapy and are mobilized immediately out of bed. Following wound healing, weight bearing as tolerated is permitted. In cases of doubt, initial partial weight bearing with about 20 kg for 4 weeks after surgery is recommended. Until patients had resumed normal activity mobilization, subcutaneous antithrombotic medication is administered.

A radiologic follow-up is performed after 3–7 days following surgery. After discharge from hospital treatment, patients are followed up at regular office visits. Clinical assessment of wound healing, condition of soft tissues, and pain with weight bearing are recorded, and sequential radiologic follow-up studies are requested at regular intervals at 6 and 12 weeks postoperatively.

Basically, nail removal is not necessary, but can be performed after complete osseous healing and according to patients' choice. In cases of doubt, CT scan is recommended to ensure proper bone healing.

11.4 Case: Reamed Intramedullary Nailing of Proximal Tibia Fractures (Figs. 11.1, 11.2 and 11.3)

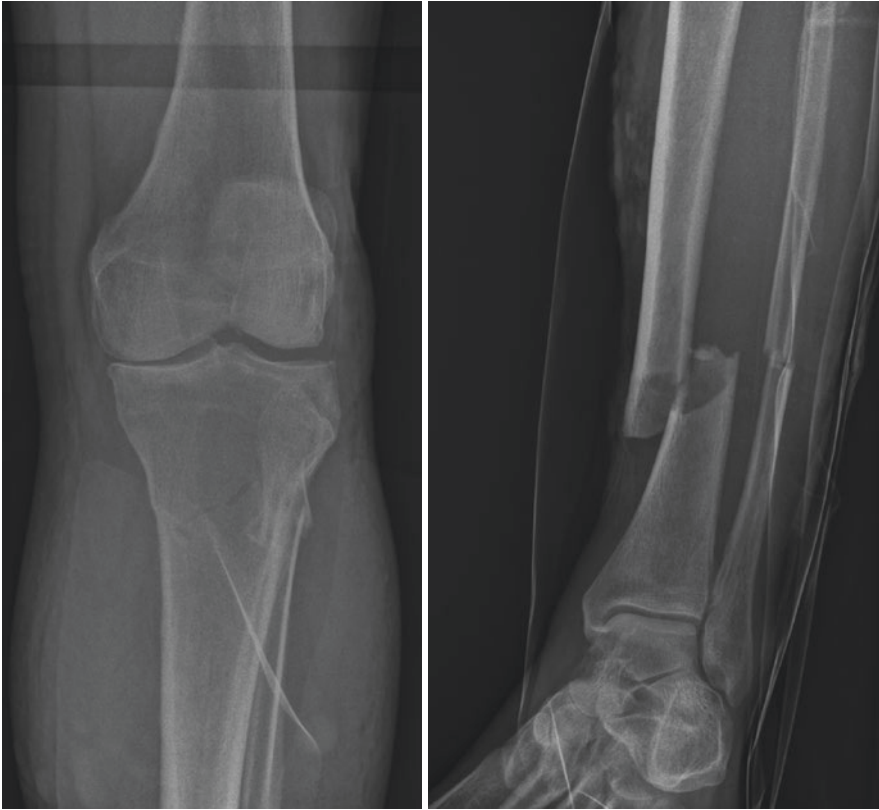
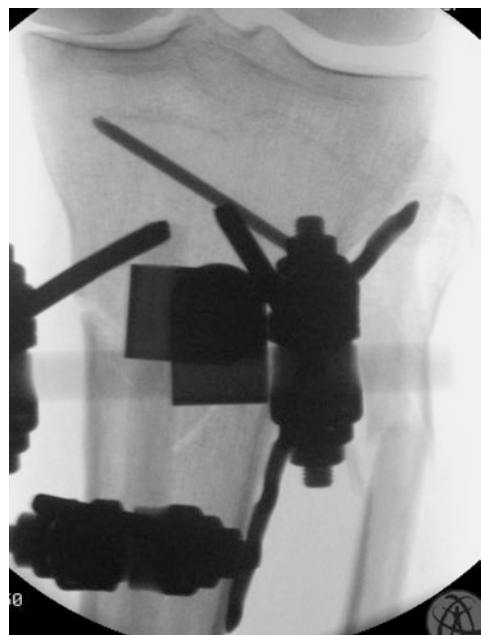


Fig. 11.1 45-year-old polytraumatized male patient after motor cycle accident with Gustilo and Anderson second degree open multi-level tibial fracture with a short proximal fracture fragment



Fig. 11.1 (continued)

Fig. 11.2 Following the Damage Control Orthopaedics concept, initial fracture fixation was performed using an external fixator



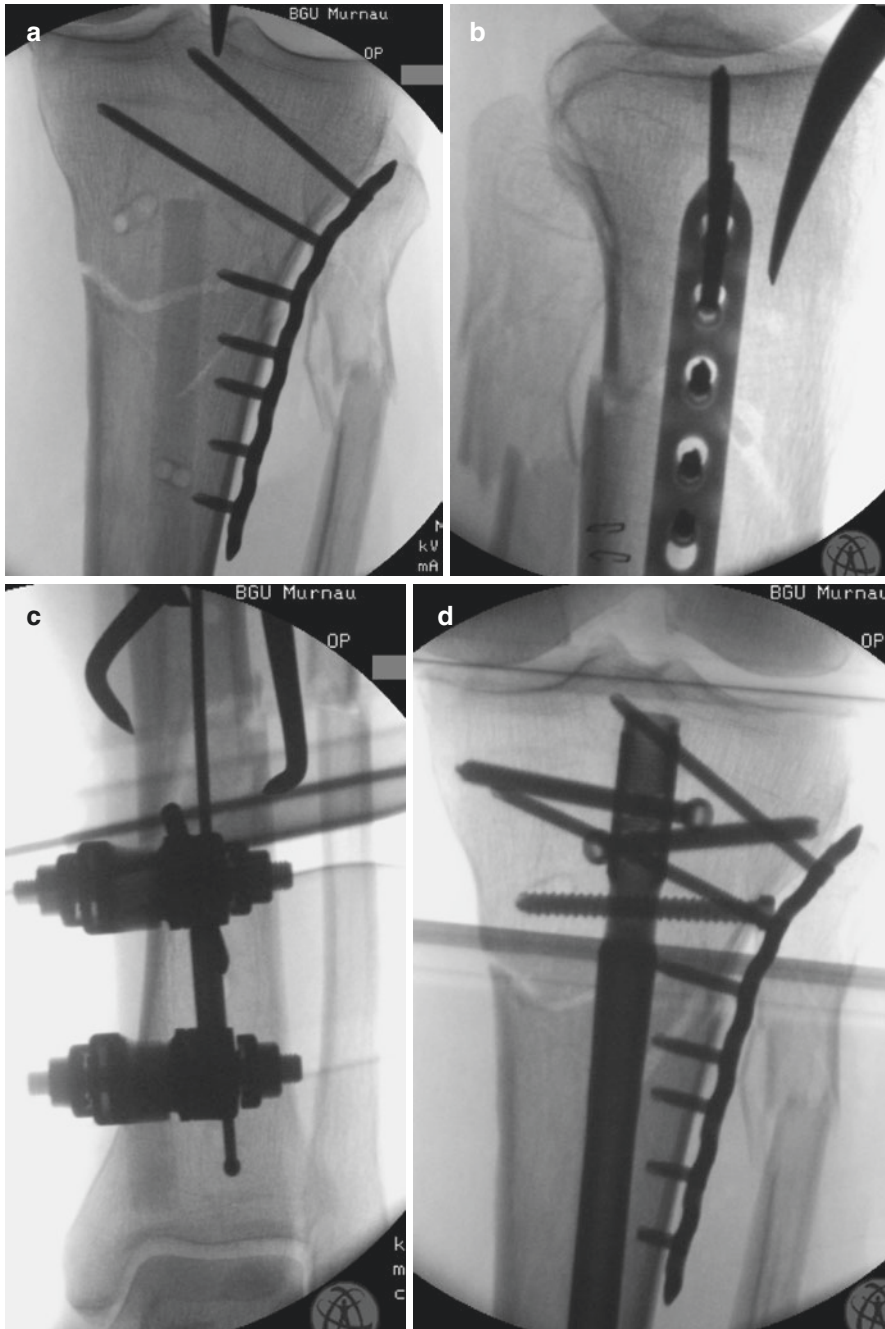


Fig. 11.3 During definitive surgery external fixator was removed, and an auxiliary locking plate was applied to fix the short proximal and the interfragmentary fragments (**a** and **b**). Then, the reamed intramedullary nail was inserted using a clamp to reduce the interfragmentary and the dis-

tal fracture fragments (**c**). The nail was locked using all available proximal and distal locking bolts (**d**, **e**, **f** and **g**). In the further clinical course, soft tissue coverage by a local muscle flap was necessary (**f**, **g**)

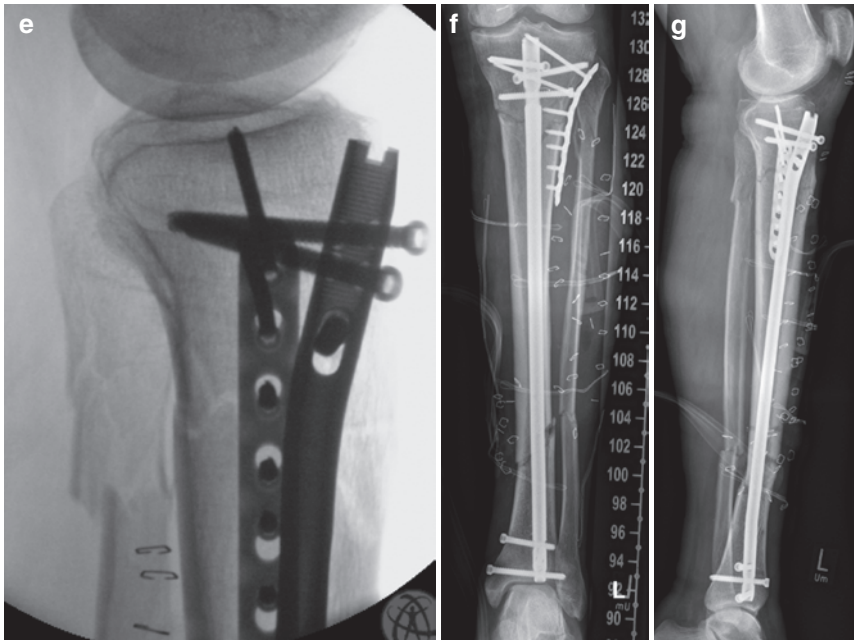


Fig. 11.3 (continued)

References

1. Kurylo JC, Tornetta P. Extra-articular proximal tibial fractures: Nail or plate. AAOS Instructional Course Lectures. 2013;62:61–77.
2. Metcalfe D, Hickson CJ, McKee L, Griffin XL. External versus internal fixation for bicondylar tibial plateau fractures: systematic review and meta-analysis. *J Orthop Traumatol.* 2015;16(4):275–85.
3. Lowe JA, Tejwani N, Yoo BJ, Wolinsky PR. Surgical techniques for complex proximal tibial fractures. *Instr Course Lect.* 2012;61:39–51.
4. Tejwani N, Polonet D, Wolinsky PR. Controversies in the intramedullary nailing of proximal and distal tibia fractures. *J Am Acad Orthop Surg.* 2014;22(10):665–73.
5. Stinner DJ, Mir H. Techniques for intramedullary nailing of proximal tibia fractures. *Orthop Clin North Am.* 2014;45(1):33–45.
6. Lang GJ, Cohen BE, Bosse MJ, Kellam JF. Proximal third tibial shaft fractures. Should they be nailed? *Clin Orthop Relat Res.* 1995;315:64–74.
7. Eastman JG, Tseng SS, Lo E, Li CS, Yoo B, Lee M. Retropatellar technique for intramedullary nailing of proximal tibia fractures: a cadaveric assessment. *J Orthop Trauma.* 2010;24:672–6.
8. Beck M, Gradl G, Gierer P, Rotter R, Witt M, Mittlmeier T. Treatment of complicated proximal segmental tibia fractures with the less invasive stabilization locking plate system. *Unfallchirurg.* 2008;111(7):493–8.
9. Ricci WM, Rudzki JR, Borrelli J Jr. Treatment of complex proximal tibia fractures with the less invasive skeletal stabilization system. *J Orthop Trauma.* 2004;18(8):521–7.
10. Pätzold R, Friederichs J, von Rügen C, Panzer S, Bühren V, Augat P. The pivotal role of the coronal fracture line for a new three-dimensional CT-based fracture classification of bicondylar proximal tibial fractures. *Injury.* 2017 Jun 27; <https://doi.org/10.1016/j.injury.2017.06.019>. Article in press
11. Hernigou P, Cohen D. Proximal entry for intramedullary nailing of the tibia. The risk of unrecognized articular damage. *J Bone Joint Surg Br.* 2000;82:33–41.
12. McConnell T, Tornetta P III, Tilzey J, Casey D. Tibial portal placement: the radiographic correlate of the anatomic safe zone. *J Orthop Trauma.* 2001;15:207–9.
13. Weninger P, Schultz A, Traxler H, Firbas W, Hertz H. Anatomic assessment of the Hoffa fat pad during insertion of a tibia nail – comparison of three surgical approaches. *J Trauma.* 2009;66:1140–5.
14. Bono CM, Levine RG, Rao JP, Behrens FF. Nonarticular proximal tibia fractures: treatment

- options and decision making. *J Am Acad Orthop Surg.* 2001;9:176–86.
15. Buehler KC, Green J, Woll TS, Duwelius PJ. A technique for intramedullary nailing of proximal third tibia fractures. *J Orthop Trauma.* 1997;11:218–23.
 16. Krettek C, Stephan C, Schandelmaier P, Richter M, Pape HC, Miclau T. The use of Poller screws as blocking screws in stabilising tibial fractures treated with small diameter intramedullary nails. *J Bone Joint Surg Br.* 1999;81:963–8.
 17. Franke J, Hohendorff B, Alt V, Thormann U, Schnettler R. Suprapatellar nailing of tibial fractures – indications and technique. *Injury.* 2016;47(2):495–501.
 18. Bühren V. Intramedullary compression nailing of long tubular bones. *Unfallchirurg.* 2000;103(9):708–20.
 19. Penzkofer R, Maier M, Nolte A, von Oldenburg G, Püschel K, Bühren V, Augat P. Influence of intramedullary nail diameter and locking mode on the stability of tibial shaft fracture fixation. *Arch Orthop Trauma Surg.* 2009;129:525–31.
 20. Hierholzer C, Friederichs J, Glowalla C, Woltmann A, Bühren V, von Rüden C. Reamed intramedullary exchange nailing in the operative treatment of aseptic tibial shaft nonunion. *Int Orthop.* 2017;41(8):1647–53.
 21. Perl M, Hierholzer C, Woltmann A, Bühren V. Technik der Austauschmarknagelung bei aseptischen hypertrophen Femurschaftpseudarthrosen. *Trauma Berufskrankh.* 2016;18(Suppl 2):181–8.
 22. Hoffmann S, Gerber C, von Oldenburg G, Kessler M, Stephan D, Augat P. Effect of angular stability and other locking parameters on the mechanical performance of intramedullary nails. *Biomed Tech (Berl).* 2015;60(2):157–64.
 23. Högel F, Gerber C, Bühren V, Augat P. Reamed intramedullary nailing of diaphyseal tibial fractures: comparison of compression and non-compression nailing. *Eur J Trauma Emerg Surg.* 2013;39:73–7.
 24. Yoon RS, Bible J, Marcus MS, Donegan DJ, Bergmann KA, Siebler JC, Mir HR, Liporace FA. Outcomes following combined intramedullary nail and plate fixation for complex tibia fractures: a multi-Centre study. *Injury.* 2015;46(6):1097–101.
 25. Hiesterman TG, Shafiq BX, Cole PA. Intramedullary nailing of extra-articular proximal tibia fractures. *J Am Acad Orthop Surg.* 2011;19(11):690–700.
 26. Xia L, Zhou J, Zhang Y, Mei G, Jin D. A meta-analysis of reamed versus unreamed intramedullary nailing for the treatment of closed tibial fractures. *Orthopedics.* 2014;37(4):e332–8.
 27. Augat P, Hoegel F, Stephan D, Hoffmann S, Bühren V. Biomechanical effects of angular stable locking in intramedullary nails for the fixation of distal tibia fractures. *Proc Inst Mech Eng H.* 2016;230(11):1016–23.