

Extra-articular Proximal Tibial Fractures: Nail or Plate?

John C. Kurylo, MD
Paul Tornetta III, MD

Abstract

The surgical goals for treating proximal tibial fractures are to restore articular congruity, the mechanical axis, and knee motion while avoiding soft-tissue complications. The fracture pattern should be correctly identified and understood. For fractures with minimal intra-articular extension, fracture fixation with an intramedullary nail can decrease the risk of infection because it uses a small incision that is not placed directly over the injured soft tissue, and it provides better axial load sharing than a plate. Using the semiextended technique, choosing the correct starting portal, incorporating blocking screws or stability screws into the fixation construct, and using mini-open reduction and internal fixation of the fracture will help achieve the goals of fracture fixation with an intramedullary nail.

All proximal tibial fractures can be treated successfully with a plate or multiple plates. When a plate is used, the surgical approach and technique should minimize soft-tissue damage and account for future surgical procedures that may be needed. Fractures with intra-articular involvement and/or comminution of the medial metaphyseal region are appropriately treated with dual plating. Extra-articular fractures without major medial comminution may be treated with a locked lateral plate. Final union rates for patients treated with either intramedullary nail or plate fixation are reported at 96% and 97%, respectively. A prospective, randomized, multicenter study is currently in progress to further clarify and advance the treatment of proximal tibial fractures.

Instr Course Lect 2013;62:61-77.

Proximal tibial fractures are challenging to treat because of the frequency of substantial soft-tissue injury, the strong deforming forces involved, and

the need for accurate alignment. This chapter will focus primarily on extra-articular proximal tibial fractures and those with minimally displaced intra-

articular extension that can be treated with intramedullary (IM) nailing or plate fixation.

Proximal tibial fractures make up 5% to 11% of all tibial injuries and typically are caused by a high-energy mechanism.¹ Because of the location of these fractures in the highly vascular and muscular area of the lower extremity, there is a higher incidence of arterial injury, muscle damage, and compartment syndrome than in diaphyseal fractures.^{2,3} Burgess et al⁴ reported that the most proximal tibial fractures result from pedestrians being struck by automobiles; the extent of the soft-tissue injury is often grossly underestimated.

The AO/Orthopaedic Trauma Association (OTA) system is the most widely used system for classifying proximal tibial fractures. Type A fractures are extra-articular, type B fractures are partially articular, and type C fractures are articular with a metaphyseal component. Both IM nails and plates are appropriate for treating type A and simple intra-articular type C1 fracture patterns⁵ (**Figure 1**).

Regardless of the fixation method chosen, traditional fracture care principles should be followed. Open fractures are treated with urgent irrigation and débridement of the devitalized tis-

Dr. Tornetta or an immediate family member serves as a board member, owner, officer, or committee member of the American Orthopaedic Association and the Orthopaedic Trauma Association; has received royalties from Smith & Nephew; and serves as a paid consultant to or is an employee of Smith & Nephew. Neither Dr. Kurylo nor any immediate family member has received anything of value from or owns stock in a commercial company or institution related directly or indirectly to the subject of this chapter.

sue. Temporary external fixation may be used, particularly if initial definitive soft-tissue coverage cannot be obtained or if the surgeon chooses to perform the definitive reduction and fixation under more ideal conditions. These fractures should be closely monitored because of the substantial risk for compartment syndrome.

Imaging

The surgical goals for treating proximal tibial fractures are to restore articular congruity, the mechanical axis, and knee motion while avoiding soft-tissue complications. To accomplish these goals, correct identification of the fracture pattern is necessary. AP and lateral radiographs may not provide adequate information on fracture

comminution, displacement, planes, and, especially, intra-articular displacement. A caudad plateau view, with the x-ray beam directed 10° caudal on the AP orientation, will provide a better understanding of the articular extension. Oblique internal and external rotation views may provide additional information about the fracture. CT will provide the best information about intra-articular extension, if present. This is particularly helpful in determining if a fracture extends into the area of portal placement for nailing (**Figure 2**). This chapter's authors typically obtain a CT scan if an intra-articular fracture is seen on radiographic studies.

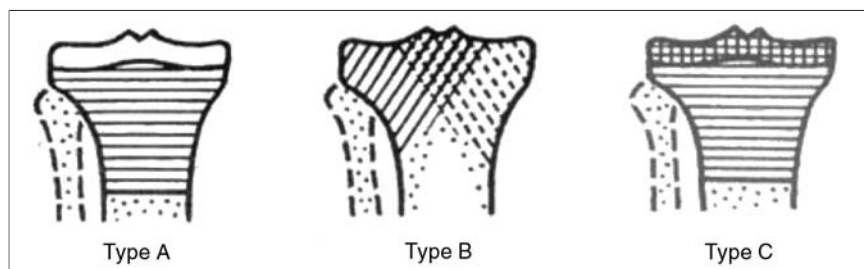


Figure 1 Illustration of the AO classification system of proximal tibial fractures. Type A fractures are extra-articular, type B fractures are partially articular, and type C fractures are articular with a metaphyseal component. (Reproduced from Hiesterman TG, Shafiq BX, Cole PA: Intramedullary nailing of extra-articular proximal tibia fractures. *J Am Acad Orthop Surg* 2011;19(10): 690-700.)

Closed Treatment

Although closed treatment of proximal tibial fractures is beyond the scope of this chapter, it is an option that should be considered. Sarmiento et al⁶ championed the nonsurgical management

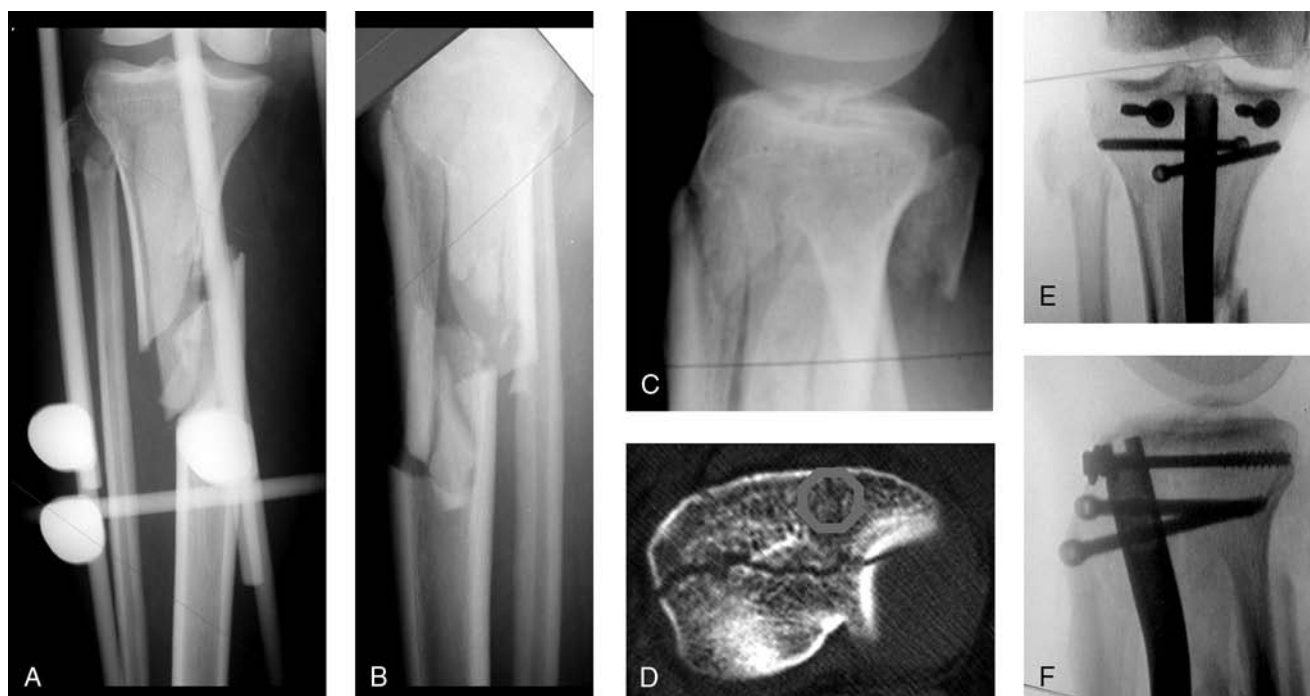


Figure 2 AP tibia (A), lateral tibia (B), and lateral knee (C) radiographs and CT scan (D) of a proximal tibial fracture showing fracture extension into the nail portal (circle). Postoperative AP (E) and lateral (F) radiographs show joint reduction with two anterior-to-posterior screws after IM nailing.

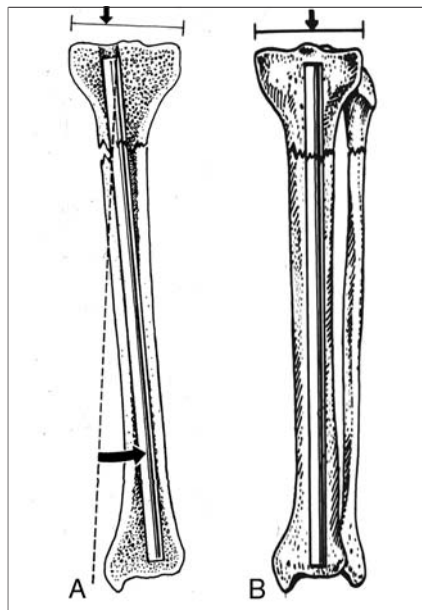


Figure 3 A, A medial starting portal for nail placement will create a valgus deformity at the fracture site. The short arrow represents a starting portal that is too medial. The dashed line represents the nail trajectory if the nail were to follow the original trajectory. However, with a starting portal that is too medial, the fracture gaps medially, a valgus deformity results, and the nail's final position is different than originally planned (large curved arrow). B, A more lateral starting portal aids in proper angulation. The short arrow represents the correct starting portal. The nail is introduced and follows the correct trajectory without causing a varus or a valgus deformity. (Reproduced from Tornetta P III: Technical considerations in the surgical management of tibial fractures. *Instr Course Lect* 1997;46:271-280.)

of proximal tibial fractures. The authors reported on 68 patients with nonarticular proximal tibial fractures who were treated with a long leg cast. In patients with proximal tibial and fibular fractures, 84% had acceptable outcomes (less than 5° of angulation in any plane) at union. Based on these results, nonsurgical treatment can be considered for patients with good alignment in the initial cast or those

Table 1

Tips for Treating Proximal Tibial Fractures With IM Nailing

Use the semiextended technique. The knee is flexed from 20° to 30°. A medial parapatellar approach with lateral subluxation of the patella is used to establish the starting portal. Special cannulas are used to protect the articular surface of the patella and trochlea.

Locate the safe zone for nail entry. On the AP view, it is located just medial to the lateral tibial spine. On the lateral view, it is located just at or behind the anterior articular surface.

Use blocking screws before nail placement to address malalignment.

Stability screws can be placed after the nail is inserted to provide additional support for the nail.

Proximal locking in the nail should use at least two multiplanar interlocking screws. Locking the screws to the nail is helpful.

who present without fracture displacement.

Treatment With an IM Nail

In early reports, proximal tibial fracture treatment with IM nailing was associated with high rates of malalignment and loss of proximal fragment fixation. In 1995, Lang et al¹ reported that 84% of their patients treated with IM nailing had sagittal malunion, and 25% had loss of reduction. Freedman and Johnson⁷ reported that 58% of proximal tibial fractures treated with IM nailing resulted in malalignment, and 83% of these fractures were segmental or comminuted. It is important to note that unlocked transverse screws were used in these early series; these screws provided only uniaxial stability and may have contributed to the loss of reduction.

Malreductions are mainly caused by errant portal placement. The most common error is a starting portal that is too medial. When nailing a proximal tibial fracture, the nail tends to lie against the lateral portion of the proximal tibia. If the portal is medial, this will result in a valgus deformity (**Figure 3**). A more lateral starting portal will prevent a valgus deformity. Flexion and posterior translation at the fracture site is the second most common deformity. Early IM nail designs exacerbated the posterior translational

deformity of the proximal tibial fracture when the proximal bend of the tibial nail was distal to the fracture site.⁸

The relative contraindications for using IM nailing for proximal tibial fractures include a narrow IM canal, inability to pass a nail because of an existing canal deformity, or the presence of a tibial base plate in a total knee arthroplasty or knee fusion. IM nailing for tibial fractures in pediatric patients should be approached with caution. Court-Brown et al⁹ reported on 52 adolescent patients between the ages of 13 and 16 years who had a tibial fracture treated with IM nailing. Partial growth arrest of the proximal tibial physis did not develop in any of the patients.

Many techniques have been shown to be helpful with complex proximal tibial nailing (**Table 1**). In general, IM nailing is an attractive method for treating proximal tibial fractures. It may decrease the risk of infection because it uses a small incision that is not placed directly over the injured soft tissue, and it provides better axial load sharing than a plate. To achieve adequate reduction with IM nailing, it is necessary to understand the characteristics of the fracture and the deforming mechanical forces acting on the proximal tibia.⁷ The patella tendon,

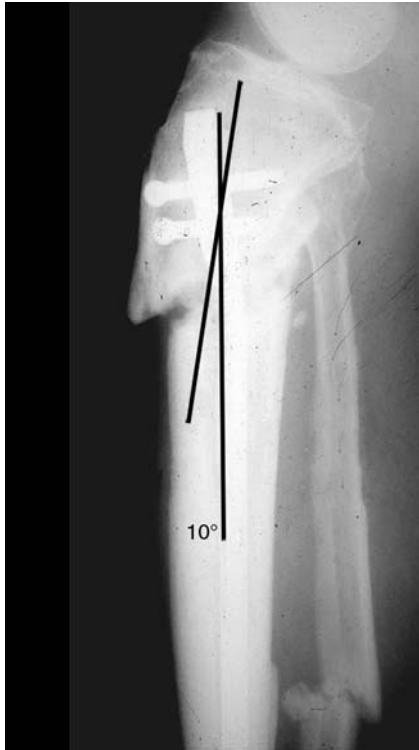


Figure 4 Radiograph showing a 10° extension deformity at the proximal tibial fracture site caused by hyperflexion nailing of the fracture. (Reproduced from Tornetta P III: Technical considerations in the surgical management of tibial fractures. *Instr Course Lect* 1997;46: 271-280.)

which is attached on the anterior tibial tubercle, will pull the proximal fragment into extension; this is a common problem seen with traditional hyperflexion nailing techniques (**Figure 4**). The strong muscular attachments on the lateral aspect of the proximal tibia restrict lateral gapping and may favor a valgus deformity. With large forces acting at the fracture gap, these forces must be reduced either directly or indirectly through the nailing approach and before fixation to prevent deformity.

Portal Placement

As with all nailing procedures, the starting portal is paramount to achieving a good outcome. Various IM nail-

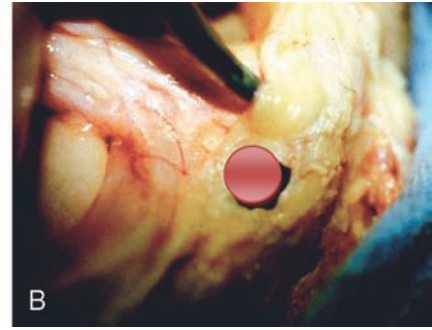
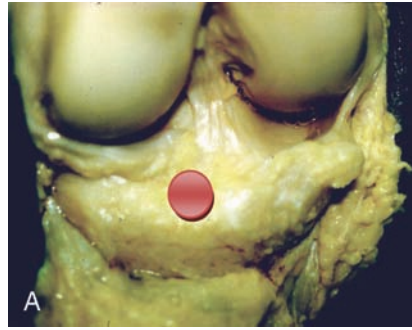


Figure 5 AP (A) and lateral (B) views of the tibia showing the safe zone (red circle) for IM nailing of a proximal tibial fracture as described by Tornetta et al.¹⁸

ing methods and techniques have been reported for treating proximal tibial fractures.¹⁰⁻¹⁷ Each method uses the same overall approach: correct starting portal, fracture reduction through direct or indirect means, and guidance of the nail down the tibial canal without creating a deformity.

Technically, the correct starting portal for nailing proximal fractures is intra-articular and as in line with the center of the canal distally as possible without causing intra-articular damage. This positioning makes nail passage easier and tends to prevent the creation of a deformity. As described by Tornetta et al,¹⁸ the safe zone for the starting portal for IM nailing of proximal tibial fractures is located 3 mm lateral to the center of the tibial tubercle, 9 ± 5 mm lateral to the midline of the tibial plateau, and 23 ± 9 mm in width (**Figure 5**). This zone allows nail placement without damaging the meniscal or articular cartilage of the knee. On an AP view of the knee, the average position of the safe zone is just medial to the lateral tibial spine.¹⁹ On the lateral view, the position is at the joint line (**Figure 6**). The proximal tibia is triangular in shape and has a large metaphyseal area. Because of the geometry of the proximal tibia, the fit is not tight at the metaphyseal bone-nail interface. The

medullary center of the tibia is just lateral to the midline¹³ (**Figure 7**). A more lateral starting portal is important because it helps prevent a valgus deformity and provides a greater propensity for the nail to be colinear with the tibial axis.

Nailing in Relative Extension

In the semiextended approach to IM nailing, the leg is positioned in approximately 20° to 30° of flexion with a small bolster under the thigh.¹⁴ A midline skin incision approximately 5 cm long is made from just above the upper pole of the patella. The deep incision is made medial to the patella and extends slightly into the vastus proximally and down as low as the upper portion of the patella tendon distally. This allows for lateral subluxation of the patella during the procedure. The tibial portal, which is located on the superior surface of the tibia, is made accessible using the trochlear groove as a conduit. A straight awl may be used to start the portal (**Figure 8**).

It is essential that the direction of the awl or the starting guidewire and reamer be checked with fluoroscopy as they are driven into the tibia. They must be directed as anteriorly as possible in the proximal tibia. In a recent study, none of the 192 patients treated with this method had greater than 5° of apex anterior angulation.²⁰ This ap-

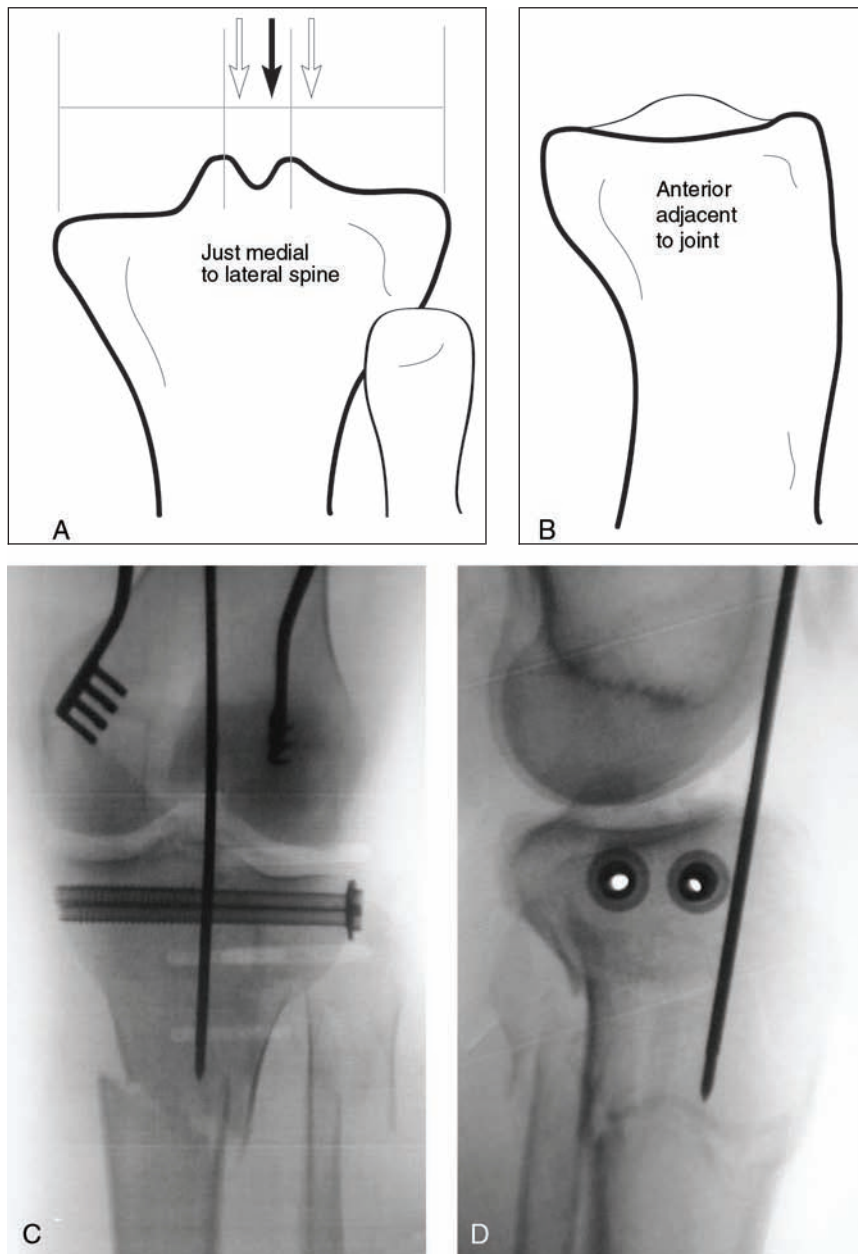


Figure 6 Illustrations of the correct nail starting point for IM nailing from AP (A) and lateral (B) views. Radiographs show the location of the correct starting portal for IM nailing. C, AP radiograph of the guidewire placed just medial to the lateral tibial spine. D, Lateral radiograph of the guidewire placed just anterior to the joint line.

proach has the potential for decreased postoperative anterior knee pain because the infrapatellar branch of the saphenous nerve and patellar tendon are avoided.²¹

A common criticism of the semiextended technique is the potential for

patella or trochlear groove injury during nailing. Since the original technique was described, special instrumentation has been developed to protect the fragile articular surface of the patella and the trochlear groove during instrumentation and nailing of

the tibial canal. The current technique uses only a 3-cm incision and cannulas to protect the trochlea and undersurface of the patella. A recent study reported that knee pain is the same in patients treated with a semiextended approach as those treated with standard hyperflexion nailing, despite a higher percentage of fractures with intra-articular extension.²⁰

Other methods for nailing proximal tibial fractures have recently been reported. These methods describe nailing in a fully or a partially extended position. The suprapatellar portal, a 2-cm vertical incision in the quadriceps mechanism directly superior to the patella, is used for nailing in full extension.¹³ Although this technique is appealing, the starting portal in the tibia is more distal and anterior than the ideal starting portal, which is not accessible until the knee is flexed 30°.^{13,22}

Proximal Fixation

To increase the stability of a proximal tibial fracture treated with IM nailing, multiplanar proximal locking is offered by various nailing systems and increases the stability of fixation.^{23,24} At least two proximal interlocking screws in different planes are recommended for proximal tibial fractures; three or more screws offer greater stability.^{23,24} The development of angular, stable interlocking screws placed through an IM nail decreases fragmentary motion and increases the stiffness of the construct.²⁵ In most systems, some method is used to lock at least the most proximal screw to the nail using an end cap. Different nailing systems offer proximal locking screw locations closer to or further from the most proximal portion of the nail.

Blocking Screws

Blocking screws essentially tighten the canal and force the nail to take a par-

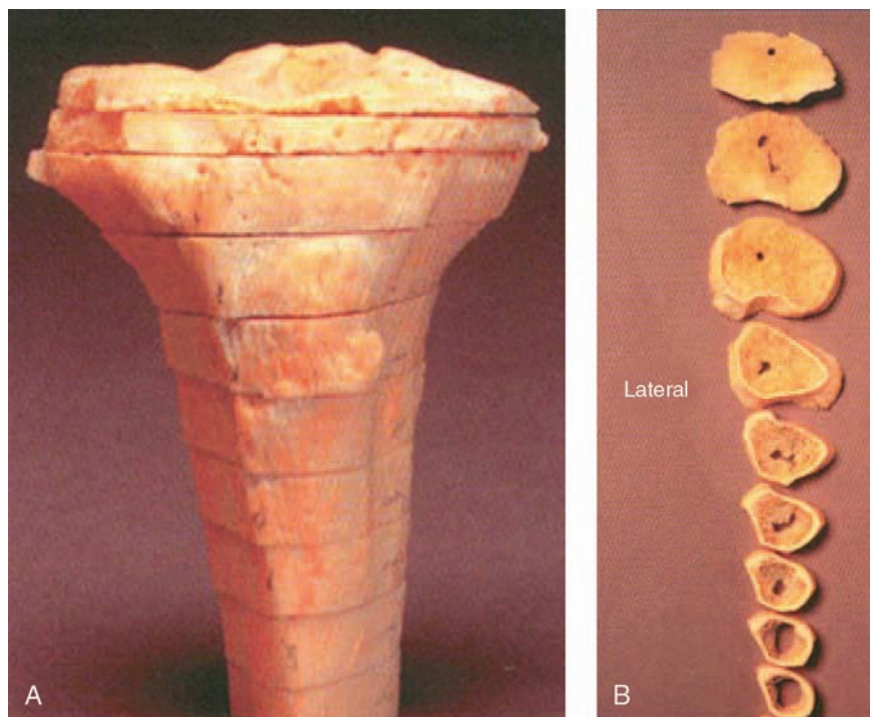


Figure 7 A, Photograph of the proximal tibia. Sectioning demonstrates the wide metaphyseal region that narrows distally to a well-defined cortical tube. B, Enface view of the tibial sections arranged in order from proximal to distal shows the more lateral trajectory a nail will take within the medullary canal of the tibia. (Reproduced with permission from Buehler KC, Green J, Woll TS, Duwelius PJ: A technique for intramedullary nailing of proximal third tibia fractures. *J Orthop Trauma* 1997;11:218-223.)

tical path to avoid malalignment in the sagittal and coronal planes. The screws are placed before nail insertion and reaming. Krettek et al¹⁵ and Cole²⁶ described their techniques for blocking screw placement to address malreduction. To prevent apex anterior angulation, a coronal blocking screw can be placed in the posterior half of the proximal fragment (**Figure 9**). Valgus malalignment can be related to a medial entry point and a laterally directed nailing insertion angle in the proximal fragment. To correct this, a blocking screw can be placed on the lateral side of the proximal fracture. If the portal is too medial, then it must be widened, even when using a lateral blocking screw. Both coronal and sagittal blocking screws can be used simultaneously to reduce multidirectional

forces. Krettek et al¹⁵ reported a mean loss of reduction between placement of the initial blocking screw and follow-up as 0.5° in the frontal plane and 0.4° in the sagittal plane. No complications were related to the use of blocking screws. When blocking screws are used appropriately, reproducible results can be expected for acceptable alignment, and the biomechanical stability of the bone-implant construct is increased 25%.^{12,27} If blocking screws are placed after IM nailing to add stability to the construct, they are called stability screws rather than blocking screws.¹²

Mini-Open Reduction and Internal Fixation

The treatment of a proximal tibial fracture with an IM nail can be aided

by using percutaneous clamps or small plates, which can be placed to obtain and maintain the reduction before nail or lag screw placement. Percutaneous reduction clamps do not increase the rate of infection.²⁸ If clamp fixation is not sufficient, unicortical plating is an option.^{29,30} A small, four- or six-hole plate is placed over the fracture or fracture fragment and is held in place with at least two unicortical screws. The plate can be placed percutaneously or via a mini-open approach. If possible, the plate should lie anteriorly to avoid the canal. Potential complications from this method include an additional incision and dissection. However, the plate may provide excellent stability for fracture reduction, and the unicortical screws can be replaced by bicortical screws after IM nailing to improve overall stability¹⁷ (**Figure 10**). This technique is not needed for all proximal tibial fractures, but it offers another method of providing stability. This is particularly helpful in open injuries in which further soft-tissue dissection is not necessary and can be detrimental.

Outcomes

Most complications seen with IM nailing of proximal tibial fractures involve malreduction (greater than 5° in any plane). The advent of the semiextended technique; angular, stable interlocking screws; and improved implant designs have resulted in average malreduction rates between 0% and 8.2%.^{20,31} Nork et al¹⁷ evaluated 456 patients with a tibial shaft fracture; 37 had a tibial fracture in the proximal quarter that was treated with IM nailing. Postoperative angulation was less than 5° in any plane for 34 of the 37 fractures (92%). Two infections were reported in the 37 patients treated with IM nailing, with both infections involving open fractures. The authors concluded that satisfactory ra-



Figure 8 A, Intraoperative photograph showing protective cannula placement for semiextended nailing via a small surgical incision. AP (B) and lateral (C) fluoroscopic images showing the correct starting portal with the semiextended technique. On the lateral view, the knee is flexed 20° to allow proper access to the correct nail entry site.

diographic alignment and union rates can be achieved; however, it is necessary to obtain the reduction before inserting the nail.

In studies of patients with anterior knee pain, 78% had sensory deficits in

the distribution area of the infrapatellar nerve.³²⁻³⁴ Even after nail removal, pain persisted in 7 of 12 patients (58%). The authors concluded that the incidence of iatrogenic damage to the infrapatellar nerve after tibial nail-

ing is high and lasting. In one study, 67% of the patients treated with trans-tendinous nailing reported anterior knee pain at the final evaluation, whereas 71% of the patients treated with paratendinous nailing reported anterior knee pain.³⁴ Katsoulis et al²¹ reported a 56% incidence of anterior knee pain. Tornetta et al²⁰ compared postoperative pain in patients treated with IM nailing in extension and in hyperflexion. Of the 192 patients studied, the same number of patients in each nailing group experienced knee pain (Table 2). None of these patients had greater than 5° of angulation in any plane.

Treatment With a Plate

Proximal tibial fractures can be successfully treated with one or multiple plates. Plates may be locked, unlocked, placed in an open fashion with clear reduction of the fracture, or placed using minimally invasive techniques and fluoroscopy. Regardless of the type of plate used or the surgical technique, the goal is to accurately restore alignment and achieve stable fracture fixation with minimal soft-tissue damage.

Anatomy of the Fracture

Most proximal tibial fractures are caused by a direct blow to the tibia. For extra-articular fractures (type A), the length of the plate used and the orientation of the fixation will depend on the amount of comminution at the fracture site and whether the fracture is purely metaphyseal or has diaphyseal extension. The two most common extra-articular patterns are oblique in nature, going from anteroinferior to posterosuperior or inferomedial to superolateral. For the simple articular (type C1) fracture pattern, intra-articular involvement is minimal, although all of the proximal tibial condyle is fractured from the remaining tibia. Bicondylar fractures with greater

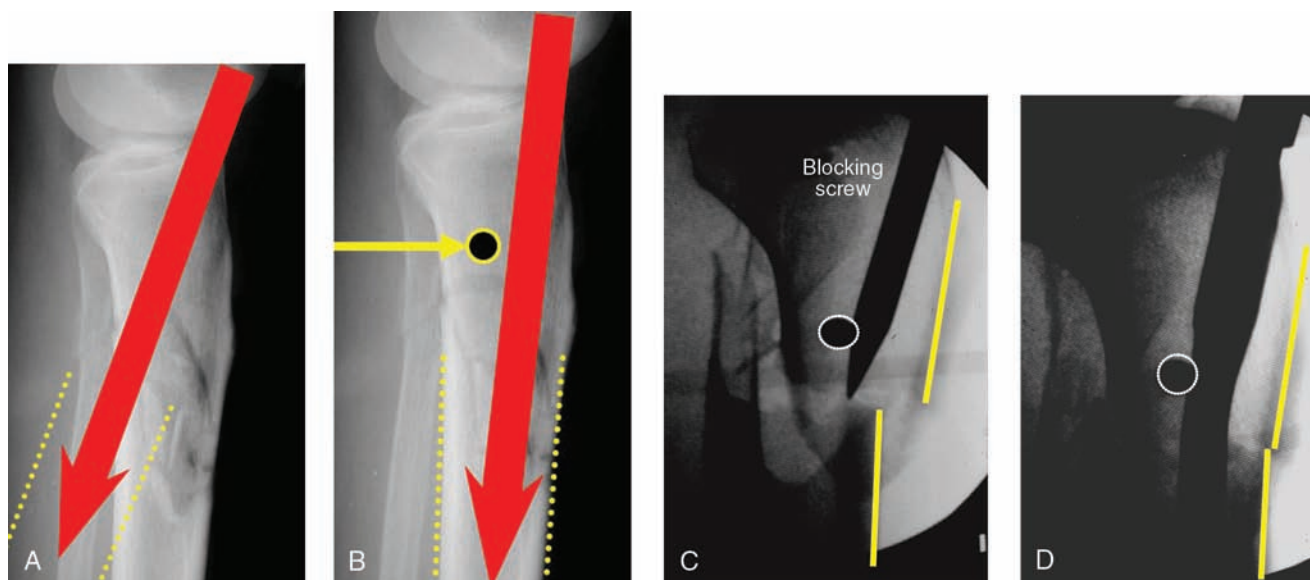


Figure 9 A, Lateral radiograph of a proximal tibial fracture. The red arrow shows the trajectory of the posterior nail. The dotted yellow lines show where the shaft will end if the nail trajectory is not changed. B, With the placement of a blocking screw (black circle) the nail trajectory changes, and the fracture is aligned (dotted yellow lines). C, Lateral radiograph of a posteriorly placed blocking screw in the proximal fragment. Note the fracture gap (yellow lines). D, After placement of the IM nail, the fracture has been reduced (yellow lines).

displacement at the level of the joint (C2 and C3 fractures), as well as fracture-dislocations, are beyond the scope of this chapter but are typically best treated with plating or fine wire external fixation (**Figure 11**).

The fracture anatomy and stability required to maintain fracture alignment will dictate the type of plate used and the location of the plate(s). A laterally based plate is frequently used for extra-articular fractures and lateral condyle fractures. Dual plating with a lateral plate combined with a medial or a posteromedial plate is more appropriate for proximal tibial fractures with greater intra-articular involvement and/or comminution of the medial metaphyseal region. The morphologic features of the medial condyle play a critical role in deciding on the type of plate(s). Laterally based, thick, locking plates are well suited for stabilizing the proximal tibia if the medial fracture is a basic transverse pattern or believed to be axially stable. The axial stability of the medial side will take pressure off

the lateral plate. The greater the metaphyseal comminution is medially, the more one may lean toward using a medial plate to help support the medial side. In such cases, a thinner locked or unlocked plate laterally will diminish soft-tissue concerns and provide adequate lateral stability unless the fracture has a long diaphyseal extension. In contrast, if the medial fracture is not complete, as in the typical fracture-dislocation pattern with a coronal plane fracture, a posteromedial plate is obligatory (**Figure 12**). This type of medial injury is observed in almost one third of bicondylar plateau fractures.³⁵

Surgical Approaches

The approach used for fracture fixation is equally as important as stabilizing the fracture itself. A lateral proximal tibial fracture can be approached with a vertical incision or an incision shaped like a lazy S or a hockey stick to allow appropriate treatment using a buttress plating technique (**Figure 13**).

These approaches can be extended distally to treat diaphyseal extension if a percutaneous reduction cannot be achieved. A direct posterior medial approach between the gastrocnemius and semimembranous muscles will allow access to the posterior aspect of the tibial plateau and posterior metaphyseal area³⁶ (**Figure 14**). With this approach, placement of a buttress plate on the posterior medial cortex will allow treatment of the fracture, with fragment-specific reduction through placement of a plate at the apex of the fracture. With any surgical approach chosen, the need for future surgical incisions over the knee, such as for a total knee arthroplasty, should be considered. Vertical incisions are generally preferred for complex intra-articular fractures (**Figure 15**). For extra-articular fractures, the joint does not have to be opened, and the incision should be large enough only to elevate the anterior compartment sufficiently to fit the head of the plate.



Figure 10 Preoperative AP radiograph (A) and CT scans (B and C) of an interarticular proximal tibial fracture with diaphyseal extension. Immediate postoperative AP (D) and lateral (E) radiographs after treatment with IM nailing and mini-open reduction and internal fixation. AP (F) and lateral (G) radiographs taken at the 5-year follow-up examination.

Locking Plates

Locked plating offers improved fixation of fractures prone to collapse on the opposite side of the plate, as seen on the medial side of proximal tibial fractures. The locked screws placed in the proximal fragment from the lateral side provide support to the medial side to aid in preventing varus collapse. In a retrospective review of 54 patients treated with locked plating for periarticular fractures of the knee, 94% of the fractures united, and no varus collapse or screw fixation failure occurred.³⁷

Table 2

Postoperative Knee Pain: Intramedullary Nailing (Semiextended Technique) Versus Standard Nailing (Hyperflexion)

Pain (0 = none, 3 = severe)	Extension Nailing	Standard Nailing
0	79%	78%
1	19%	10%
2	2%	8%
3	0%	4%

To improve fracture fixation, specific techniques and tips are helpful (Table 3). This chapter's authors recommend that metaphyseal fixation for

locked plates should use as many large diameter screws (for example, 5.7 mm) as the system allows. Using a larger screw diameter and a large number of

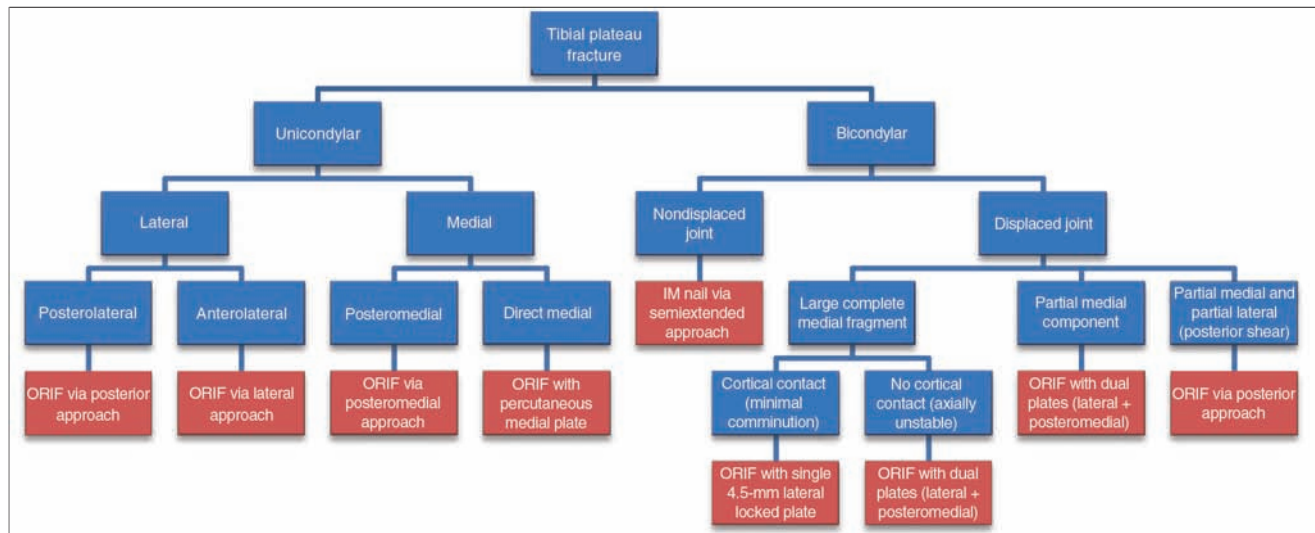


Figure 11 This chapter's authors treatment algorithm for the fixation of proximal tibial fractures. ORIF = open reduction and internal fixation.

screws in the metaphysis provides a larger area of metaphyseal bone support. When adding locking screws to a plate construct in the diaphysis, bicortical screws will increase the construct's rigidity.³⁸ The mechanical strength of the plate-fracture construct with unicortical diaphyseal locking screws is inferior to bicortical fixation, especially in torsion.^{37,39,40} However, it is unclear how many fixation points are needed in the diaphysis. Although stable fixation is needed, a construct that is too stiff can diminish callus formation. The working length must be optimized for each fracture. If an anatomic reduction is achieved, a stiff construct may be beneficial. In contrast, if a bridge plate technique is used, leaving several holes open near the fracture may benefit healing. The surgeon must determine the goals of fixation and choose a construct that meets those criteria.

After metaphyseal reduction has been obtained, provisional fixation and a formal radiographic check of the alignment should be done. Extramedullary guides can be used to confirm alignment from the knee to the ankle in proximal tibial fractures. An align-

ment board, a radiopaque board with a single vertical line down the tibial shaft and multiple horizontal lines at 90° angles to the single vertical line, can be placed on top of the leg to assess the plateau-to-shaft alignment and the plateau-to-ankle alignment (**Figure 16**). Using the board, starting at the level of the knee joint down to the ankle, locking plate fixation can be performed with confidence that the alignment of the knee to the ankle is correct. Although no studies have been performed comparing final alignment with and without the use of an alignment board, additional intraoperative tools to verify alignment may provide the surgeon with more information to aid in fracture reduction and alignment. If such a board is not available, this chapter's authors suggest provisional fixation of the plate and obtaining full-length AP and lateral tibial radiographs to confirm alignment.

After alignment is confirmed, an unlocked screw or large clamp typically is used to compress the proximal portion of the plate to the metaphyseal region, creating friction before the fixation is locked. In younger patients with good bone quality, the diaphyseal

portion of the fracture can be fixed with all unlocked screws. In revision cases or in patients with osteoporotic bone, a hybrid technique is used. Nonlocking screws are placed within the locking plate to reduce the fracture/bone to the plate. The nonlocking screws can then be replaced by locking screws. The hybrid system offers the benefits of using nonlocking screws for fracture compression and locking screws for fracture stability. The expense of locked constructs is substantially higher than for nonlocked constructs, with most of the cost attributed to the price of the locked screws.^{41,42}

A limitation of locking plates is that reduction must be maintained before placing any locked screws. Capturing smaller fractures or portions of the articular surface, especially the posterior medial proximal tibial fracture fragment, is not predictable with laterally placed locking plate systems.^{41,43-45}

Nonlocking Plates

Nonlocking plates rely on friction generated by the compression force between the head of the screw and plate for fracture fixation. These types of



Figure 12 Example of bicondylar tibial plateau fracture treated with dual plating. AP radiograph (A) and CT scans (B and C) of a bicondylar tibial plateau fracture treated initially with a spanning external fixator. AP (D) and lateral (E) postoperative radiographs after the fracture was treated with condylar plate fixation

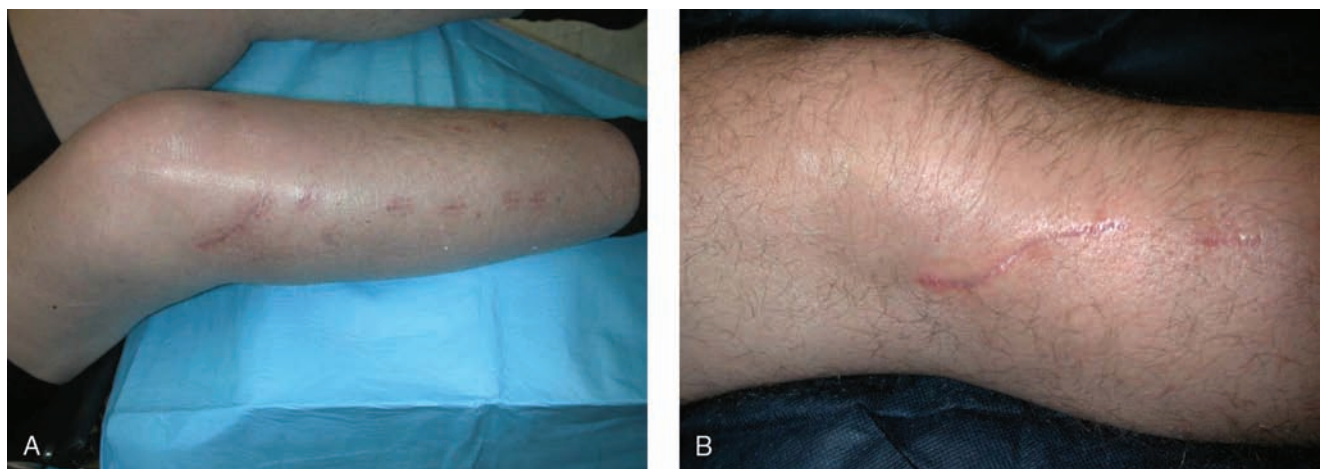


Figure 13 Clinical photographs of the leg after healing of a proximal tibial fracture treated with a mini-open approach (A) and the lazy S approach (B).

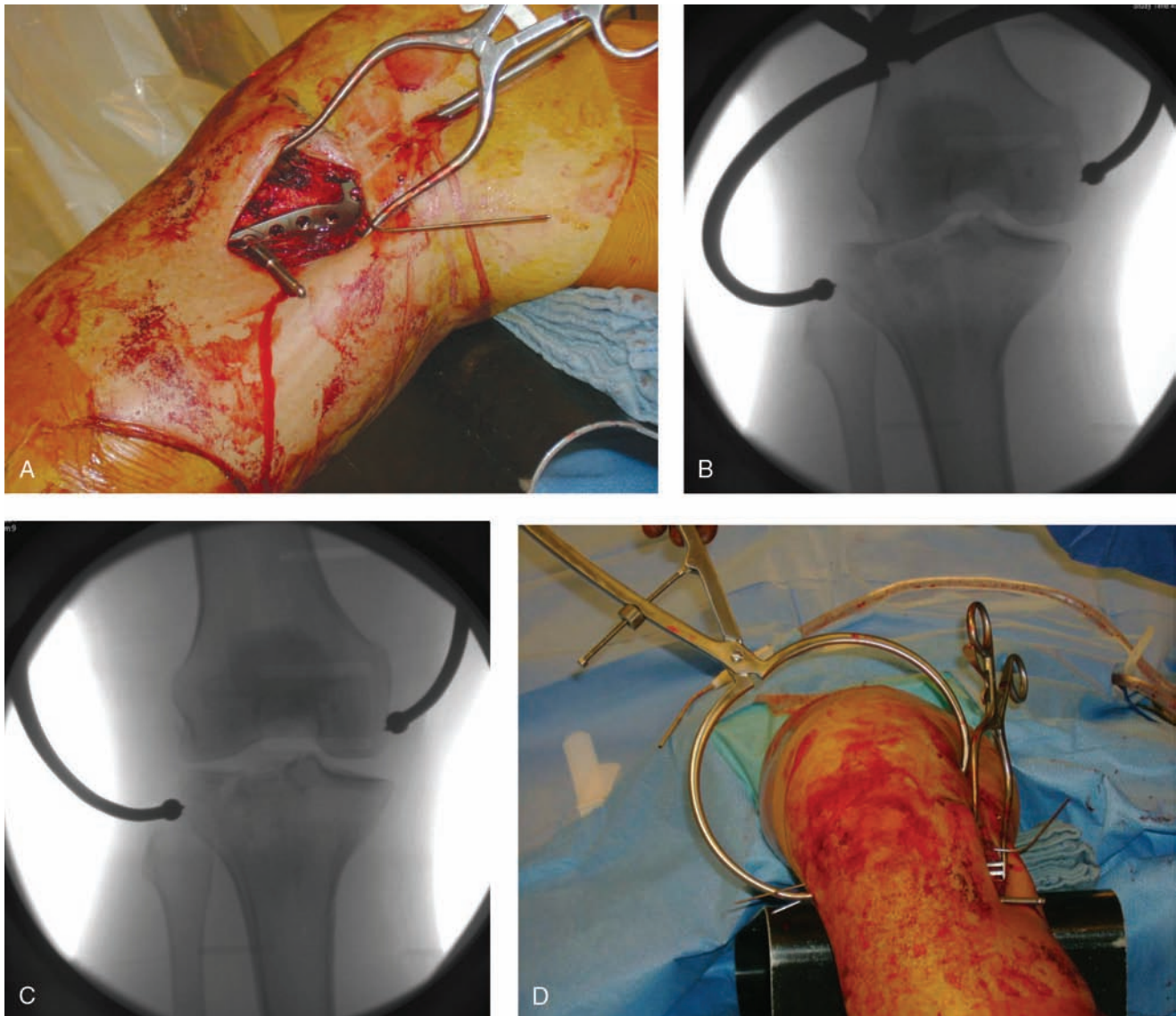


Figure 14 A, Intraoperative photograph of the location of the posterior medial plate on completion of the posterior proximal approach to the medial fracture. Wire and a provisional fixation pin are used to temporarily hold the plate in place. Intraoperative fluoroscopic images of the location of the clamp before (B) and after (C) reduction. D, AP view of the periarticular reduction clamp.

constructs fail because of the loss of force at the screw-plate interface and have limited ability to provide axial stability (the bone fracture fragment and screw move as a single unit and become displaced). Because of their design, fracture fixation using only nonlocking plates has limited use in extra-articular proximal tibial fractures. For unstable proximal tibial fractures, both medial and lateral column plates

should be used because a single lateral plate will lead to varus collapse. In rare instances of a very stable medial extension, a single unlocked lateral plate will suffice.

Nonlocking fixation can be augmented with external fixation. The addition of an external fixator can help prevent fracture malalignment and provide time for soft-tissue healing. A low malunion rate and a 5% deep in-

fection rate have been reported in treating medial and lateral proximal tibial fractures with a medial external fixator and a 4.5-mm, contoured, dynamic compression plate placed laterally.^{46,47}

Percutaneous Plating

The fracture pattern, the need for stability, the condition of the soft-tissue sleeve, and the judgment of the treat-

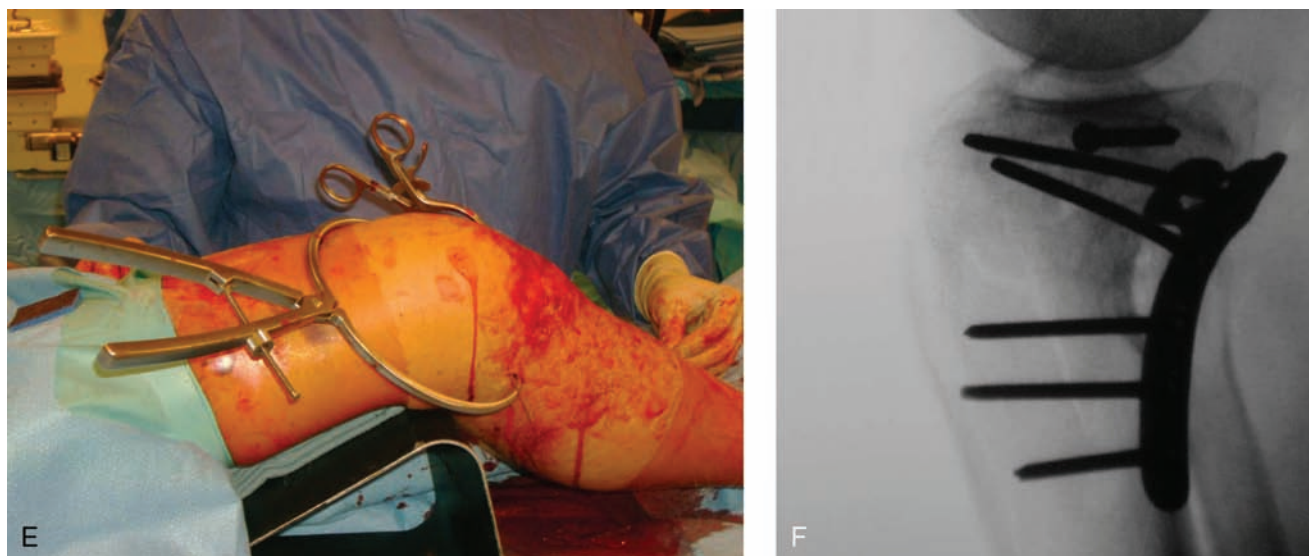


Figure 14 (continued) **E**, Lateral view of the periarticular reduction clamp. **F**, Lateral radiograph showing the final location of the plate on the posterior medial aspect of the tibia.

ing surgeon regarding his or her ability to reduce the fracture percutaneously should be considered when choosing percutaneous fixation versus an open approach.⁴⁸ Percutaneous placement and locked fixation are not synonymous. Any plate may be placed with minimally invasive techniques. The decision to open the fracture is based on the ability to reduce it closed or with percutaneous clamps, external distractors, and plating as well as the desired type of fixation (anatomic with compression versus bridge plating).

The Less Invasive Stabilization System (LISS; Synthes, Paoli, PA) was the first implant used in percutaneous treatment of proximal tibial fractures. It is a precontoured lateral implant placed in a submuscular manner. The reported advantages of the LISS system, and percutaneous plating in general, are a smaller incision and less muscle dissection.^{49,50}

Studies of percutaneous plating have reported that malalignment occurs in 10% of patients, submuscular fixation of the tibia does not cause a substantial rise in leg compartment

pressures, and the incidence of compartment syndrome is not increased.^{50,51} Ricci et al⁵² confirmed that percutaneous plating can be used to successfully treat complex proximal tibial fractures without the need for additional medial stabilization. However, because the plate is placed without direct surgical visualization of its entire length, the superficial peroneal nerve is at substantial risk for injury during lateral percutaneous screw placement.⁵³ When the plate is in the region of the neurovascular structures, a small 1- to 2-cm incision should be made, and the anterior compartment should be retracted posteriorly to expose the plate for safe screw placement.

Complications

Infection, malunion, nonunion, and painful hardware necessitating removal are possible complications of plating. Postoperative infection rates range from 1.6% with lateral fixation only to 8.4% with dual plating.⁵⁴ The infection rate for percutaneous plating ranges from 0% to 6%.^{51,53-57} Even

with open visualization and reduction of a proximal tibial fracture, malreduction can occur. The rate of initial loss of fracture reduction using percutaneous plating ranges from 0% to 4%.^{51,53-57} Phisitkul et al⁵⁸ reported on 37 proximal tibial fractures treated with plate fixation. Complications included eight deep wound infections (22%), eight fracture malalignments (22%), and three fractures with loss of reduction (8%). Fractures treated initially with an external fixator followed by plating had a 5% deep wound infection rate and 4% nonunion rate.⁵⁶ Cole et al⁴⁹ reported a 5% incidence of hardware removal after plate fixation.

Outcomes

Lindvall et al⁵⁹ reported on 29 patients with proximal tibial fractures treated with IM nailing and 42 treated with plating. There was no statistical difference in the final union rate after any additional procedures, with 96% union in the IM nailing group and 97% in the plate group. Apex anterior malreduction was the most preventable form of malreduction in both



Figure 15 AP (A) and lateral (B) radiographs of a proximal tibial intra-articular fracture with diaphyseal extension. C, Intraoperative fluoroscopic view of the temporary reduction of the proximal fracture using wires and clamps. The fracture was approached via a single middle incision. Postoperative AP (D) and lateral (E) radiographs. Note the staple line going down the midline of the knee and the limited extent of the incision that stops just distal to the proximal portion of the plate. The distal end of the plate is placed with elevation of the anterior compartment.

groups (36% in the IM nailing group and 15% in the plate group). The rate of implant removal was three times greater in the plating group, and additional surgical techniques were used during reduction in the IM nailing group. The interval change from immediate postoperative radiographs to healed radiographs was substantially different between the groups.

Treatment choice also influences the time to weight bearing. Studies of IM nailing reported commencement

of full weight bearing 0 to 16 weeks after surgery. For fractures treated with plating, full weight bearing began 6 to 13 weeks after surgery.^{15,49,60}

Future Directions

A prospective multicenter study is currently in progress to evaluate plating or nailing of proximal tibial fractures. The Intramedullary Nails Versus Plate Fixation Re-Evaluation study (IMPRESS) is a randomized controlled trial in which patients with a

fracture of the proximal metaphysis of the tibia will be surgically managed with one of two strategies. The first strategy involves fracture fixation with a reamed, interlocking IM nail. The second strategy involves open reduction and internal fixation of the fracture with a locking periarticular plate. The hypothesis of the study is that there will be no difference in the two groups with respect to primary and secondary outcome measures. It is hoped that the results from this study

Table 3
Tips for Treating Proximal Tibial Fractures With a Plate

The surgical approach and technique should minimize soft-tissue damage and account for future surgical procedures that may be needed, such as a total knee arthroplasty.

Fractures with intra-articular involvement and/or comminution of the medial metaphyseal region are appropriately treated with dual plating (a lateral plate combined with a medial or posteromedial plate). Extra-articular fractures without major medial comminution may be treated with a locked lateral plate.

The reduction can be aided with a distractor or an external fixator to gain length.

An alignment guide or a full-length lower extremity radiograph should be used to confirm intraoperative alignment before full definitive fixation.

The number and size of locking screws should be maximized for metaphyseal fixation.

If diaphyseal fixation is required, a long plate is recommended to provide appropriate stability.

Distal diaphyseal fixation of a lateral plate should be done by mobilizing the anterior compartment posteriorly to place screws under direct vision.

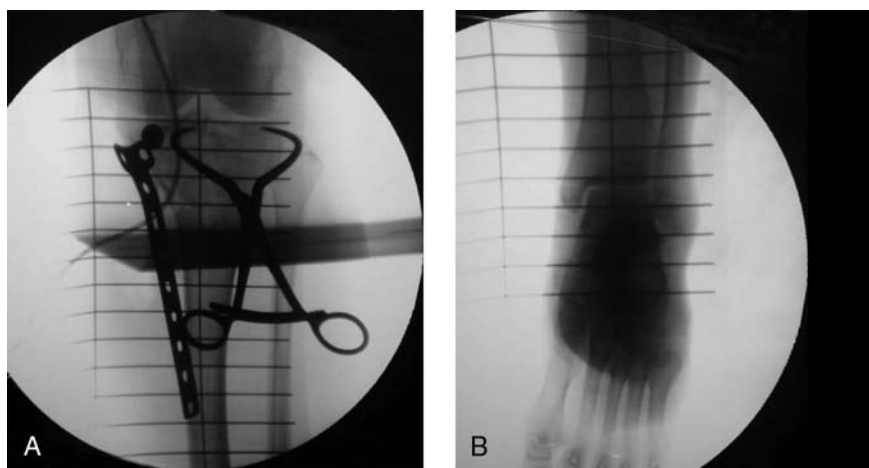


Figure 16 **A**, Intraoperative radiograph of the proximal tibia just before placement of the plate. The horizontal lines are from the alignment board placed behind the lower extremity. **B**, The alignment board aids in visualizing the axis of the tibia and the joint line at the knee and ankle to help prevent malalignment.

will further clarify and advance the treatment of proximal tibial fractures.

Summary

Plates provide excellent fixation of intra-articular extension fractures and are most useful when the soft-tissue environment is amenable to dissection in the area of the proximal tibia. IM nailing provides added stability through diaphyseal extension, but it requires special techniques and an understanding of the nail's relationship to medullary canal mechanics. Direct in-

cisions in the area of the proximal tibia are avoided, and the soft-tissue sleeve is respected. Hybrid constructs of both minimal plating and IM nailing are viable options. The optimal method of treating a proximal tibial fracture is the method that best balances soft-tissue management and fracture reduction and alignment.

References

1. 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.

2. Halpern AA, Nagel DA: Anterior compartment pressures in patients with tibial fractures. *J Trauma* 1980;20(9):786-790.
3. Borrelli J Jr, Prickett W, Song E, Becker D, Ricci W: Extraosseous blood supply of the tibia and the effects of different plating techniques: A human cadaveric study. *J Orthop Trauma* 2002;16(10):691-695.
4. Burgess AR, Poka A, Brumback RJ, Flagle CL, Loeb PE, Ebraheim NA: Pedestrian tibial injuries. *J Trauma* 1987;27(6):596-601.
5. AO Foundation: Müller AO classification of fractures: Long bones. Switzerland, AO Foundation website. http://www.aofoundation.org/Documents/mueller_ao_class.pdf. Accessed August 6, 2012.
6. Sarmiento A, Kinman PB, Latta LL, Eng P: Fractures of the proximal tibia and tibial condyles: A clinical and laboratory comparative study. *Clin Orthop Relat Res* 1979;145:136-145.
7. Freedman EL, Johnson EE: Radiographic analysis of tibial fracture malalignment following intramedullary nailing. *Clin Orthop Relat Res* 1995;315:25-33.
8. Henley MB, Meier M, Tencer AF: Influences of some design parameters on the biomechanics of the unreamed tibial intramedullary nail. *J Orthop Trauma* 1993;7(4):311-319.
9. Court-Brown CM, Byrnes T, McLaughlin G: Intramedullary nailing of tibial diaphyseal fractures in adolescents with open physes. *Injury* 2003;34(10):781-785.
10. Benirschke SK: Proximal one-third tibial fracture solutions. *Orthop Trans* 1995;18:1055-1056.
11. Vidyadhara S, Sharath KR: Prospective study of the clinico-

- radiological outcome of interlocked nailing in proximal third tibial shaft fractures. *Injury* 2006; 37(6):536-542.
12. Ricci WM, O'Boyle M, Borrelli J, Bellabarba C, Sanders R: Fractures of the proximal third of the tibial shaft treated with intramedullary nails and blocking screws. *J Orthop Trauma* 2001;15(4): 264-270.
13. Buehler KC, Green J, Woll TS, Duwelius PJ: A technique for intramedullary nailing of proximal third tibia fractures. *J Orthop Trauma* 1997;11(3):218-223.
14. Tornetta P III, Collins E: Semiextended position of intramedullary nailing of the proximal tibia. *Clin Orthop Relat Res* 1996;328: 185-189.
15. 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(6): 963-968.
16. Wysocki RW, Kapotas JS, Virkus WW: Intramedullary nailing of proximal and distal one-third tibial shaft fractures with intraoperative two-pin external fixation. *J Trauma* 2009;66(4):1135-1139.
17. Nork SE, Barei DP, Schildhauer TA, et al: Intramedullary nailing of proximal quarter tibial fractures. *J Orthop Trauma* 2006; 20(8):523-528.
18. Tornetta P III, Riina J, Geller J, Purban W: Intraarticular anatomic risks of tibial nailing. *J Orthop Trauma* 1999;13(4): 247-251.
19. 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(3): 207-209.
20. Tornetta P III, Steen B, Ryan S: Tibial metaphyseal fractures: Nailing in extension. Orthopaedic Trauma Association 2008 Annual Meeting. Scientific Program Papers: Session 2: Tibia/Polytrauma. <http://www.hwb.org/ota/am/ota08/otapa/OTA080207.htm>. Accessed August 6, 2012.
21. Katsoulis E, Court-Brown C, Giannoudis PV: Incidence and aetiology of anterior knee pain after intramedullary nailing of the femur and tibia. *J Bone Joint Surg Br* 2006;88(5):576-580.
22. Eastman J, Tseng S, 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(11):672-676.
23. Hansen M, Blum J, Mehler D, Hessmann MH, Rommens PM: Double or triple interlocking when nailing proximal tibial fractures? A biomechanical investigation. *Arch Orthop Trauma Surg* 2009;129(12):1715-1719.
24. Sayana MK, Davis BJ, Kapoor B, Rahmatalla A, Maffulli N: Fracture strain and stability with additional locking screws in intramedullary nailing: A biomechanical study. *J Trauma* 2006;60(5): 1053-1057.
25. Horn J, Linke B, Höntzsch D, Guerguiev B, Schwieger K: Angle stable interlocking screws improve construct stability of intramedullary nailing of distal tibia fractures: A biomechanical study. *Injury* 2009;40(7):767-771.
26. Cole D: Intramedullary fixation of proximal tibia fractures. *Tech Orthop* 1998;13(1).
27. Krettek C, Miclau T, Schandelmaier P, Stephan C, Möhlmann U, Tschern H: The mechanical effect of blocking screws ("Poller screws") in stabilizing tibia fractures with short proximal or distal fragments after insertion of small-diameter intramedullary nails. *J Orthop Trauma* 1999;13(8): 550-553.
28. Tang P, Gates C, Hawes J, Vogt M, Prayson MJ: Does open reduction increase the chance of infection during intramedullary nailing of closed tibial shaft fractures? *J Orthop Trauma* 2006;20(5): 317-322.
29. Matthews DE, McGuire R, Free-land AE: Anterior unicortical buttress plating in conjunction with an unreamed interlocking intramedullary nail for treatment of very proximal tibial diaphyseal fractures. *Orthopedics* 1997;20(7): 647-648.
30. Kim KC, Lee JK, Hwang DS, Yang JY, Kim YM: Provisional unicortical plating with reamed intramedullary nailing in segmental tibial fractures involving the high proximal metaphysis. *Orthopedics* 2007;30(3):189-192.
31. Hiesterman TG, Shafiq BX, Cole PA: Intramedullary nailing of extra-articular proximal tibia fractures. *J Am Acad Orthop Surg* 2011;19(11):690-700.
32. Leliveld MS, Verhofstad MH: Injury to the infrapatellar branch of the saphenous nerve: A possible cause for anterior knee pain after tibial nailing? *Injury* 2012;43(6): 779-783.
33. Keating JF, Orfaly R, O'Brien PJ: Knee pain after tibial nailing. *J Orthop Trauma* 1997;11(1): 10-13.
34. Toivanen JA, Väistö O, Kannus P, Latvala K, Honkonen SE, Järvinen MJ: Anterior knee pain after intramedullary nailing of fractures of the tibial shaft: A prospective, randomized study comparing two different nail-insertion techniques. *J Bone Joint Surg Am* 2002;84(4):580-585.
35. Barei DP, O'Mara TJ, Taitsman LA, Dunbar RP, Nork SE: Frequency and fracture morphology of the posteromedial fragment in bicondylar tibial plateau fracture patterns. *J Orthop Trauma* 2008; 22(3):176-182.

36. Medvecky MJ, Noyes FR: Surgical approaches to the posteromedial and posterolateral aspects of the knee. *J Am Acad Orthop Surg* 2005;13(2):121-128.
37. Haidukewych G, Sems SA, Huebner D, Horwitz D, Levy B: Results of polyaxial locked-plate fixation of periarticular fractures of the knee. *J Bone Joint Surg Am* 2007;89(3):614-620.
38. Dougherty PJ, Kim DG, Meisterling S, Wybo C, Yen Y: Biomechanical comparison of bicortical versus unicortical screw placement of proximal tibia locking plates: A cadaveric model. *J Orthop Trauma* 2008;22(6):399-403.
39. Kregor PJ, Stannard J, Zlowodzki M, Cole PA, Alonso J: Distal femoral fracture fixation utilizing the Less Invasive Stabilization System (L.I.S.S.): The technique and early results. *Injury* 2001;32(suppl 3):SC32-SC47.
40. Egol KA, Kubiak EN, Fulkerson E, Kummer FJ, Koval KJ: Biomechanics of locked plates and screws. *J Orthop Trauma* 2004;18(8):488-493.
41. Haidukewych GJ: Innovations in locking plate technology. *J Am Acad Orthop Surg* 2004;12(4):205-212.
42. Gardner MJ, Helfet DL, Lorich DG: Has locked plating completely replaced conventional plating? *Am J Orthop (Belle Mead NJ)* 2004;33(9):439-446.
43. Althausen PL, Lee MA, Finckmeier CG, Meehan JP, Rodrigo JJ: Operative stabilization of supracondylar femur fractures above total knee arthroplasty: A comparison of four treatment methods. *J Arthroplasty* 2003;18(7):834-839.
44. Fulkerson E, Koval K, Preston CF, Iesaka K, Kummer FJ, Egol KA: Fixation of periprosthetic femoral shaft fractures associated with cemented femoral stems: A biomechanical comparison of locked plating and conventional cable plates. *J Orthop Trauma* 2006;20(2):89-93.
45. Raab GE, Davis CM III: Early healing with locked condylar plating of periprosthetic fractures around the knee. *J Arthroplasty* 2005;20(8):984-989.
46. Bolhofner BR: Indirect reduction and composite fixation of extra-articular proximal tibia fractures. *Clin Orthop Relat Res* 1995;315:75-83.
47. Gerber A, Ganz R: Combined internal and external osteosynthesis: A biological approach to the treatment of complex fractures of the proximal tibia. *Injury* 1998;29(suppl):C22-C28.
48. Lowe JA, Tejwani N, Yoo BJ, Wolinsky PR: Surgical techniques for complex proximal tibial fractures. *Instr Course Lect* 2012;61:39-51.
49. Cole PA, Zlowodzki M, Kregor PJ: Treatment of proximal tibia fractures using the less invasive stabilization system: Surgical experience and early clinical results in 77 fractures. *J Orthop Trauma* 2004;18(8):528-535.
50. Cole PA, Zlowodzki M, Kregor PJ: Compartment pressures after submuscular fixation of proximal tibia fractures. *Injury* 2003;34(suppl 1):A43-A46.
51. Boldin C, Fankhauser F, Hofer HP, Szyszkowitz R: Three-year results of proximal tibia fractures treated with the LISS. *Clin Orthop Relat Res* 2006;445:222-229.
52. 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):521-527.
53. Deangelis JP, Deangelis NA, Anderson R: Anatomy of the superficial peroneal nerve in relation to fixation of tibia fractures with the less invasive stabilization system. *J Orthop Trauma* 2004;18(8):536-539.
54. Higgins TF, Klatt J, Bachus KN: Biomechanical analysis of bicondylar tibial plateau fixation: How does lateral locking plate fixation compare to dual plate fixation? *J Orthop Trauma* 2007;21(5):301-306.
55. Stannard JP, Wilson TC, Volgas DA, Alonso JE: Fracture stabilization of proximal tibial fractures with the proximal tibial LISS: Early experience in Birmingham, Alabama (USA). *Injury* 2003;34(suppl 1):A36-A42.
56. Egol KA, Tejwani NC, Capla EL, Wolinsky PL, Koval KJ: Staged management of high-energy proximal tibia fractures (OTA types 41): The results of a prospective, standardized protocol. *J Orthop Trauma* 2005;19(7):448-456.
57. Schütz M, Käb MJ, Haas N: Stabilization of proximal tibial fractures with the LIS-System: Early clinical experience in Berlin. *Injury* 2003;34(suppl 1):A30-A35.
58. Phisitkul P, McKinley TO, Nepola JV, Marsh JL: Complications of locking plate fixation in complex proximal tibia injuries. *J Orthop Trauma* 2007;21(2):83-91.
59. Lindvall E, Sanders R, Dipasquale T, Herscovici D, Haidukewych G, Sagi C: Intramedullary nailing versus percutaneous locked plating of extra-articular proximal tibial fractures: Comparison of 56 cases. *J Orthop Trauma* 2009;23(7):485-492.
60. Gustilo RB, Simpson L, Nixon R, Ruiz A, Indeck W: Analysis of 511 open fractures. *Clin Orthop Relat Res* 1969;66:148-154.