Surgical Techniques

Pearls and Pitfalls With Intramedullary Nailing of Proximal Tibia Fractures

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Abstract

Intramedullary fixation of proximal tibia fractures remains a challenging surgical technique, with malalignment reported as high as 84%. The pull from the extensor mechanism, the hamstring and iliotibial band, in addition to the lack of endosteal fit from the nail, has made surgical fixation of these fractures difficult. Commonly held principles to reduce angular deformity include ensuring adequate imaging, obtaining an optimal start and trajectory for the implant, and obtaining and maintaining a reduction throughout the duration of the procedure. Some adjunctive techniques to assist in the application of these principles include use of a semiextended technique, clamping, blocking screws/wires, and unicortical plates. Understanding the challenges involved in intramedullary nailing of proximal tibia fractures and considering a wide array of techniques in the orthopaedic surgeon's armamentarium to combat these challenges is important.

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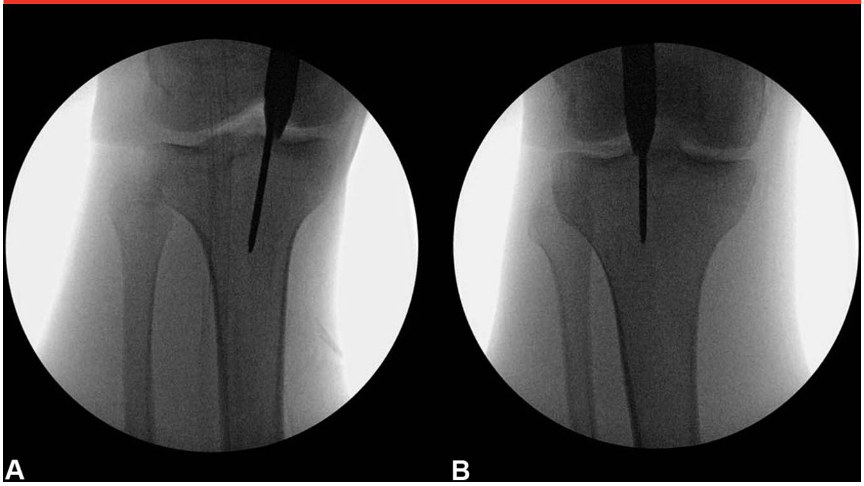
The application of intramedullary (IM) devices has expanded with the advancement of instrumentation and implants. The minimal soft-tissue disruption and biomechanical advantages of IM nails have led to further applications in fracture care, with IM fixation techniques becoming an essential instrument in the orthopaedic surgeon's armamentarium. However, as the indications for IM nailing have widened, new complications have arisen.

Proximal tibia diaphyseal fractures (OTA classification type 42A, 42B, and 42C) present particular challenges with IM fixation. Malalignment in the form of valgus and procurvatum has been reported from 44% to 84%, with earlier reports recommending against the use of IM implants in the treatment of these fractures.[1–5] The forces exerted from the extensor mechanism, the hamstring and iliotibial band, in addition to the lack of endosteal fit from the nail, have made IM fixation of proximal tibia fractures challenging.[6] Adjunctive techniques to reduce malalignment have focused on obtaining an ideal start point for nail entry, semiextended positioning for the procedure, use of clamps and blocking screws, and the application of unicortical plates for provisional reduction.[5,7–22] This article highlights surgical strategies to overcome the above-mentioned difficulties and provides injury-specific technical tips.

Tips to Optimize Results

The potential pitfalls of proximal tibia fracture nailing can often be related to the following: appropriate equipment, appropriate start and trajectory for the nail, and obtaining and maintaining a reduction throughout the procedure. The following are tips to help guide in

Figure 1



A, Internally rotated view of the knee with the patella over the medial femoral condyle and the fibula minimally overshadowed by the lateral tibia. Internal rotation causes radiographic medialization of the starting point. **B**, Proper AP view of the knee showing the same starting point now with a proper start point just medial to the lateral tibial spine. The patella is now centered and the fibula bisected by the lateral tibia.

achieving an adequate final alignment of challenging proximal tibia fractures.

Plan Ahead

The importance of understanding the local anatomy, pathoanatomy of the injury, and implants and how they are designed cannot be overemphasized. All surgeons, regardless of experience, can benefit from thorough preoperative planning. A CT scan of the tibia may be helpful with fractures close to the joint to rule out intra-articular injuries, as these can be further displaced with nail application.

Preparations for surgical techniques and instruments are made available according to the preoperative plan, including setup and positioning, reduction methods, and implants. Typically, the patient is positioned supine on a radiolucent table with a bump under the ipsilateral hip to avoid excessive external rotation of the proximal tibia, and the C-arm is brought from the contralateral uninjured side.

Recognize Troublesome Injury Patterns

Recognizing proximal patterns, including those that may seem more diaphyseal but behave as proximal fractures, is integral to avoiding malalignment. Fractures that include large anterior cortical spikes with notable posterior comminution may act as proximal metaphyseal fractures, regardless of their more central shaft location. Ballistic injuries can be particularly difficult to distinguish, as their behavior can differ from more standard shaft patterns. Furthermore, fractures with comminution, particularly on the lateral side, can be problematic, as this condition allows the fracture to collapse in valgus and can lead to eccentric reaming as the reamer falls away from the contralateral cortex and into the defect.

Recognizing intra-articular extension of proximal shaft or metaphyseal fractures is also important. CT scans can often characterize the fracture morphology, allowing for proper preoperative planning and strategic placement of screws before nailing. These screws should be placed before instrumentation for the nail, as fractures can be propagated and displaced, and to ensure they remain out of the proposed path of the nail.

Understanding the Design Features of Modern Implants

Nail designs with respect to the location of the Herzog curve can accentuate apex anterior deformities. In the study by Henley et al,[23] it was noted that the more distal the bend in the nail, the more likely the fracture displacement, a phenomenon referred to as the wedge effect. IM devices with more proximal Herzog curves have been more amenable to maintenance of fracture reduction with passage through the canal, which has largely been an issue with earlier generations of nails and has resolved with the evolution of more modern designs with more proximal Herzog curves.

Proximal locking options have also evolved, with more modern nail designs typically having three or more proximal locking holes. Numerous biomechanical and clinical studies have suggested the limited stability associated with single locking bolts in the proximal segment of IM devices used to treat proximal tibial shaft fractures.[23,24] Hansen et al[25] reported that adding a third proximal screw to fix proximal tibial fractures increased axial stiffness by 61%. In the study by Wolinsky et al,[26] adding a third proximal transverse locking screw increased axial stiffness by 28% and torsional stiffness by 15% to 28%. With regard to screw orientation, Henley et al reported that in comminuted bone increased stiffness was noticed with two coronal screws in comparison with two oblique screws, although this phenomenon was explained by insertion of oblique screws more proximally in softer metaphyseal bone.[24] However, the use of medial-to-lateral oblique locking screws, particularly when the screw hole is approximately 30 mm from the proximal end of the implant, has been found to place the common peroneal nerve at risk.[27] Numerous locking options proximally have increased with modern nail designs, with oblique options in addition to medial-to-lateral options available. Further modifications have additionally included angular stable locking bolts, although their clinical utility remains in question.[28]

Imaging

Obtaining appropriate views to evaluate the location of the start point and the trajectory is paramount to the prevention of deformity. In the coronal plane, ensuring that a proper AP is obtained is important, as an excessive external rotation view of the knee will cause medial placement of the starting wire, and an internal rotation view will cause lateral placement of the starting wire. In the study by Walker et al,[29] the lateral edge of the tibia bisecting the fibular head was used to ensure a proper AP view was obtained. A centered patella can additionally be used to verify proper rotation. Similarly, obtaining a proper lateral of the knee with overlapping of the femoral condyles will allow for proper placement of the wire (Figure 1).

Ease of imaging can be increased with the use of the semiextended position for nailing. The suprapatellar technique has recently gained popularity, allowing for unencumbered access to the knee from the contralateral surgical side without being obscured by radiolucent triangles and other adjunctive devices used to assist in infrapatellar nailing.

Start Point

Obtaining a proper start point is paramount to the prevention of malalignment in proximal tibia fracture nailing.

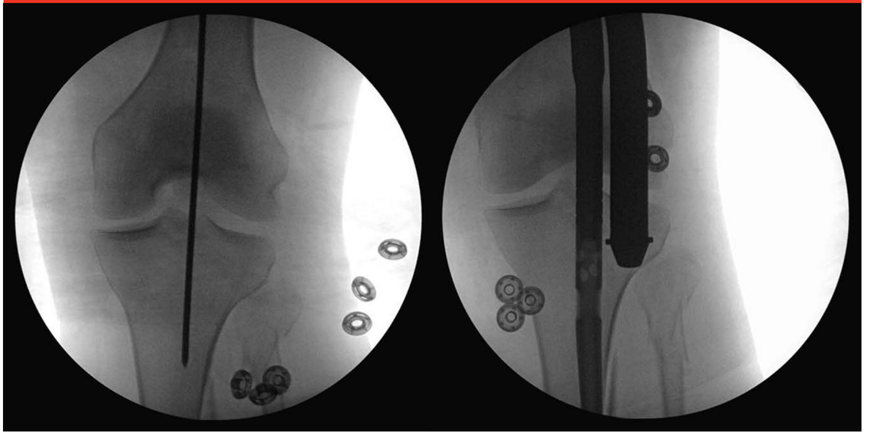
Figure 2

AP and lateral fluoroscopic images showing proper starting guidewire placement using a suprapatellar technique. Note the use of guidewire without cannula placement.

In the study by Tornetta et al,[8] the ideal "safe zone" for IM nail placement was located 9.1 ± 5 mm lateral to the midline of the tibial plateau and 3 mm lateral to the center of the tibial tubercle. This zone radiographically correlated with a point just medial to the lateral tibial spine. With regard to the sagittal orientation, the optimal starting point is proximal to the anterior edge of the articular margin.

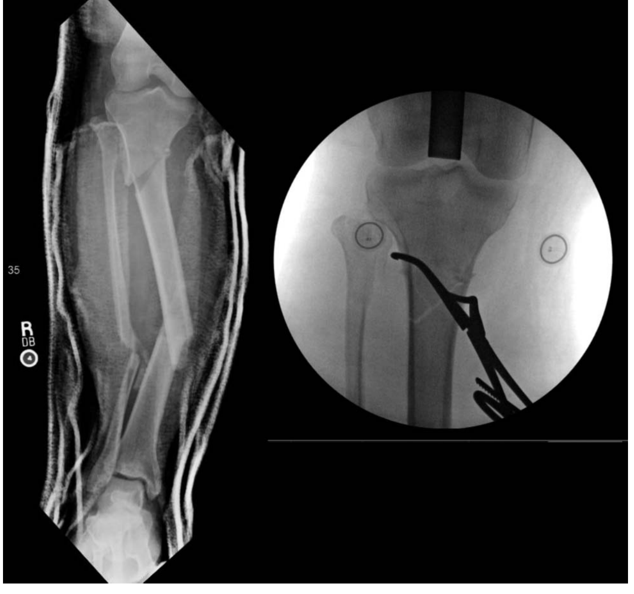
When obtaining a start point with semiextended nailing, various approaches have been used. Semiextended nailing was first introduced by Tornetta et al,[9] where a formal medial parapatellar arthrotomy with lateral subluxation of the patella was used to gain access to the tibial portal. They reported successful outcomes in 25 patients treated with this approach and noted only two cases of damage to the trochlear groove, but cautioned that care must be taken throughout the procedure to ensure integrity of the trochlear groove. A modified medial miniarthrotomy was suggested in a subsequent article by Ryan et al,[30] finding no difference in knee pain with this approach in comparison with the standard infrapatellar approach. However, concern remains using the retropatellar portal and the potential for patellofemoral cartilage damage. In the study by Sanders et al,[31] 36 patients treated with the suprapatellar technique using a retropatellar portal were reviewed, and 15 had arthroscopies before and after surgery. They reported 13 of 15 patients with no immediate cartilage damage, and the finding of grade II chondromalacia in

Figure 3



AP fluoroscopic images showing the proper start point with an improper trajectory leading to lateral displacement of the nail and valgus deformity.

Figure 4



AP fluoroscopic images showing proper clamp placement leaving the anterior and lateral musculature lateral to the tine of clamp.

Figure 5

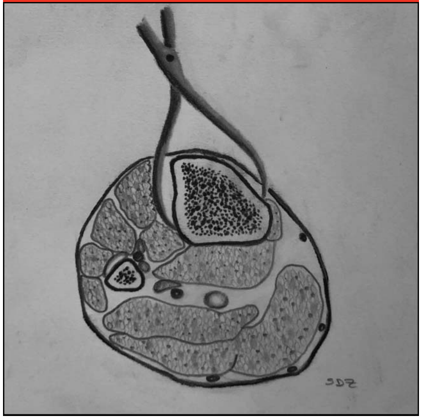


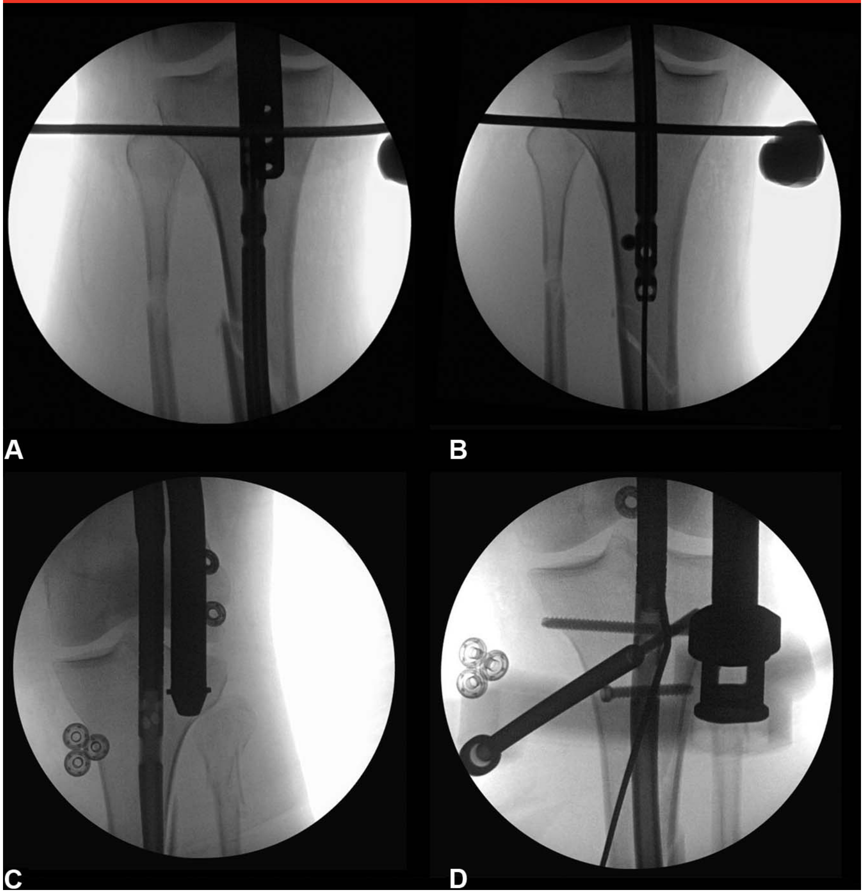
Diagram showing one potential technique for clamp placement. The lateral tine is first placed just lateral to the tibial crest and slid subperiosteally along the lateral border of the tibia. Once positioned, the medial tine is placed.

two patients did not correspond with subsequent 1-year MRI results or clinical findings. In a randomized prospective study by Chan et al,[32] 11 of 25 patients underwent suprapatellar nailing and had prenail and postnail insertion patellofemoral joint arthroscopy in addition to 1-year MRIs. They reported three patients with postnail changes in articular cartilage and five patients with chondromalacia on MRI. However, MRI findings of chondromalacia did not correlate with either prenail or postnail insertion arthroscopy, and no patient with postnail insertion arthroscopic changes had patellofemoral pain at 1-year follow-up.

Although suprapatellar nailing has simplified some aspects of nailing proximal tibia fractures, one particular issue that has arisen is obtaining a posterior enough start point, as often the cannula can be limiting as it is introduced into the relatively narrow patellofemoral joint space. One potential solution to this issue is to delay placement of the cannula until after placement of the starting guidewire (Video: Supplemental Digital Content 1, http://links.lww.com/JAAOS/A384; Supplemental Digital Content 2, http://links.lww.com/JAAOS/A385; Supplemental Digital Content 3, http://links.lww.com/JAAOS/A386; Supplemental Digital Content 4, http://links.lww.com/JAAOS/A387; Supplemental Digital Content 5, http://links.lww.com/JAAOS/A388; Supplemental Digital Content 6, http://links.lww.com/JAAOS/A389; Supplemental Digital Content 7, http://links.lww.com/JAAOS/A390; Supplemental Digital Content 8, http://links.lww.com/JAAOS/A391; Supplemental Digital Content 9, http://links.lww.com/JAAOS/A392; Supplemental Digital Content 10, http://links.lww.com/JAAOS/A393; Supplemental Digital Content 11, http://links.lww.com/JAAOS/A394; Supplemental Digital

Content 12, http://links.lww.com/JAAOS/A395; Supplemental Digital Content 13, http://links.lww.com/JAAOS/A396; Supplemental Digital Content 14, http://links.lww.com/JAAOS/A397; Supplemental Digital Content 15, http://links.lww.com/JAAOS/A398; Supplemental Digital Content 16, http://links.lww.com/JAAOS/A399; Supplemental Digital Content 17, http://links.lww.com/JAAOS/A400). After the incision through the quad tendon, the knee is hyperextended and an Army-Navy retractor placed underneath the patella. The starting guidewire is then safely introduced through the patellofemoral joint space, with care to avoid injury to the articular cartilage. Once introduced, the Army-Navy retractor is removed, and the knee is flexed to 40° to 50° (usually with the use of a bump). Hyperflexion to this degree, while helpful in obtaining a proper trajectory, can worsen fracture malalignment, particularly a procurvatum deformity. The ideal starting point is then obtained (Figure 2). Once this point is obtained and the starting wire driven through the metaphyseal region of the proximal tibia, the cannula is placed over the starting guidewire with the knee once again hyperextended to allow maximum space for the patellofemoral joint. Allowing placement of the starting guidewire without being encumbered by the cannula allows for efficient and easier placement of the guidewire. Care must be taken to ensure that the trajectory of the starting wire remains within the middle of the tibia, as lateral deviation can lead to accentuation of the valgus deformity (Figure 3).

Figure 6



AP fluoroscopic images showing (**A**) the trajectory that is too lateral leading to the valgus deformity with nail insertion, (**B**) the blocking screw placed in the previous nail path allowing for reduction with passage of the nail, (**C**) the trajectory that is too lateral leading to the valgus deformity, and (**D**) the wire placed in the concavity of the deformity, with subsequent bending of the wire. Note the wire is bent but not broken, and the deformity is corrected.

With infrapatellar nailing, a medial parapatellar or patellar tendon split is most commonly used, each with their own unique challenges. With a medial parapatellar approach, it is at times difficult to start as lateral as is necessary for a proper starting point. With a patellar split, remaining parallel to the anterior cortex is often difficult because the patella prevents posterior placement and a posterior to anterior trajectory of the guidewire. This process can at times be prevented with hyperflexion. In particular, a radiolucent triangle can be used to begin a start point, with the trajectory obtained with removal of the radiolucent triangle and full flexion of the knee.

Maintenance of the starting point throughout reaming is also essential for prevention of malalignment. As sequential reaming takes place, preventing reamer "creep" is important, with progressive anterior migration of the starting point. As the guidewire sits adjacent to the patella or trochlea, the guidewire is anteriorly displaced against the starting hole. As the reamer heads engage the guidewire, eccentric reaming of the starting hole can occur, with widening and anterior migration. This issue can largely be circumvented with care to ensure that reaming does not take place until the reamer is seated in the metaphysis of the proximal tibia and by manual removal of the reamer through the starting hole.

Figure 7

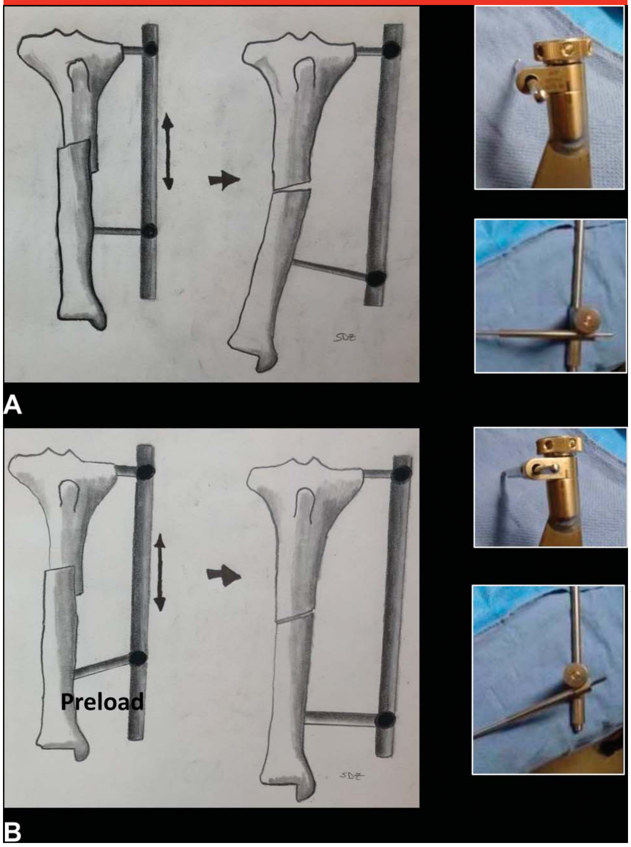


Diagram showing (**A**) placement of distractor without preloading the pins in an advantageous position accentuating a valgus deformity with distraction. Photographs of the femoral distractor pin without preload is shown to the right. (**B**) Diagram showing positioning of the Schanz pins in a preloaded position helping with coronal deformities with distraction. Photographs of the femoral distractor pin preloaded are shown to the right.

Clamping

Some proximal fractures are amenable to percutaneous clamp placement (Figure 4). Care again must be taken to ensure that placement of the clamp does not cause notable trauma to the soft tissue, in particular the anterior and lateral musculature of the leg. Although some have advocated the use of wide clamps or even periarticular clamps to prevent soft-tissue trauma,[19,33,34] an alternative method includes placing a small stab incision just off the lateral crest of the tibia. One tine of the clamp is then slid across the bone laterally, leaving all musculature lateral to the tine, which will allow for clamp placement that will bypass the anterior and lateral musculature entirely, preventing soft-tissue trauma (Figure 5). Ensuring that during clamp placement, the tines of the clamp are engaged with the bone rather than the "jaws" of the tenaculum is imperative. Furthermore, integrity of the clamp can lessen during reaming and nail application can be reinforced with manual manipulation or with use of a Kocher clamped against the ratcheting mechanism to prevent loosening and/or shifting.

Blocking Wires Versus Screws

Blocking wires and screws can be placed at multiple points to effectively reduce the effective metaphyseal space and increase the effective diameter of the nail.[14–16,35] In particular to proximal tibia fractures, they are commonly placed in the concavity of the deformity in the proximal segment. Alternatively, the screws are placed in a space where the surgeon does not want the nail to occupy.

It is often times difficult to judge the location of the blocking screw that will provide the most optimal force vector for reduction. At times, improperly placed blocking screws can provide little to no correction of the deformity or, conversely, can be too aggressive, leading to inability to pass the reamer, increased hoop stresses that can propagate or cause a fracture, and/or overreduction. Typically, the nail is removed, and the previous nail path visualized under fluoroscopy. The blocking screw is subsequently placed near or slightly within the previous nail path in the concavity of the deformity and at a minimum of 1 cm from the fracture, and sequential reaming proceeds before the final nail application. Alternatively, the use of 2-mm wires, or greater in diameter, allows for more flexibility in terms of placement, with overly aggressive placement often times not leading to overreduction but rather bending of the wire. Bending of the wire can commonly be seen, but breakage does not typically occur, as can be found with the use of blocking drill bits (Figure 6). Wires less than 2 mm are often not robust enough to provide notable correction in either the coronal or the sagittal planes. Furthermore, if a single wire is inadequate to reduce the fracture, a series of cascading wires can be placed to assist in properly placing the implants toward the correct path. However, a Kocher must be clamped to the wire closest to the skin to prevent driving the wire from anterior to posterior with passing of a spinning reamer. Alternatively, the reamer can be pushed forward without being spun to prevent driving the wire posteriorly. In addition, if wires are used, they should be removed at the conclusion of all interlocks being placed.

Universal Distractor

Use of a universal distractor can serve multiple purposes when nailing challenging proximal tibia fractures,[5,17] which can allow for unwavering traction and maintenance of length throughout the duration of the procedure. Furthermore, strategic placement of the pins can allow for introduction of a varus moment to help prevent valgus alignment common in proximal tibia fractures. Schanz pins can optimally be placed near the proximal tibial physeal scar in the mid-sagittal to slightly posterior plane on the lateral image, which can dually serve as a blocking screw to prevent apex anterior angulation at the fracture. Distally, placement along the distal physeal scar provides an optimal location for prevention of interference with the path for the nail. In addition, with placement of the distractor medially, this process can often further introduce a valgus moment to the fracture. With the use of "preloading" the distractor, this process can prevent further valgus malalignment (Figure 7).

Unicortical Plates

The use of unicortical plates for provisional reduction has gained popularity in recent years. Some studies have been found to suggest similar complication rates between use of unicortical plates versus standard reduction methods.[21,22] In the setting of an open fracture, unicortical plates have been widely used because it reduces the biologic cost. In closed fractures, the use of unicortical plates nonetheless requires the opening of a closed fracture to achieve reduction. This phenomenon is not without its potential complications including increased periosteal stripping, and most importantly, infection, and is not typically used by the authors. When unicortical plates are used, typically 2.7-mm plates and above are used with 6- to 8-mm screws. These plates remain in place until final placement of all interlocks and are often removed before closure.

Conclusions

The treatment of proximal tibia fractures with IM fixation remains complex and challenging. Complications including malalignment have been widely reported in the literature, with rates as high as 84%. Commonly held principles to reduce angular deformity include ensuring adequate imaging, obtaining an optimal start and trajectory for the implant, and obtaining and maintaining a reduction throughout the duration of the procedure. Some adjunctive techniques to assist in the application of these principles include use of a semiextended technique, clamping, blocking screws/wires, and unicortical plates. Understanding the challenges involved in IM nailing of proximal tibia fractures and considering a wide array of techniques in the orthopaedic surgeon's armamentarium to combat these challenges is important.

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