Techniques for Intramedullary Nailing of Proximal Tibia Fractures

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KEYWORDS
- Proximal tibia fracture • Extra-articular • Suprapatellar nailing • Retropatellar nailing • Semiextended nailing • Blocking screws

KEY POINTS
- Despite poor early results with intramedullary nailing of extra-articular proximal tibia fractures, improvements in surgical technique and implant design modifications have resulted in more acceptable outcomes.
- Prevention of the commonly encountered apex anterior and/or valgus deformities remains a challenge when treating these injuries.
- It is necessary for the surgeon to recognize that prevention of apex anterior and/or valgus deformities presents a constant challenge and it is their responsibility to know how to neutralize these forces.
- Surgeons should be comfortable using a variety of the reduction techniques presented to minimize fracture malalignment.

INTRODUCTION

Proximal tibia fractures have presented a treatment challenge for orthopedic surgeons. Soft tissue concerns with open plating techniques resulted in the increased use of either percutaneous plating methods or intramedullary nail (IMN) fixation, which has the added benefit of being a load-sharing device to allow early weight bearing. Malalignment was common with early nailing techniques and implant designs as demonstrated by several series published during the 1990s.1,2 In a radiographic analysis of 133 tibia fractures treated with IMN fixation, Freedman and Johnson2 reported that 7 (58%) of the 12 proximal tibia fractures were malaligned, compared with an overall malalignment rate of all tibia fractures of 12% in the study. This experience was shared by Lang and colleagues1 who evaluated the results of 32 extra-articular proximal third tibia fractures treated with an IMN. At final follow-up, 27 (84%) of 32 fractures were malaligned more than 5° in the sagittal or coronal plane. As a result, the authors stated that they have limited their use of IMN for proximal third fractures.

The common deformity seen in proximal third tibia fractures is an apex anterior and/or valgus deformity. There are two main factors that complicate reduction of extra-articular proximal tibial fractures when treated with closed IMN: deforming forces of the proximal tibia (mainly extension of the proximal segment caused by pull of the extensor mechanism, but also forces from pull of the
hamstrings and iliotibial band in different patterns); and the spaciousness of the intramedullary canal proximal to the metaphyseal flare.3–5

IMN fixation offers several significant advantages over other treatment methods, such as plate fixation, because patients can be allowed to weight bear earlier and the surgery can be performed without making large skin incisions over a potentially compromised soft tissue envelope. The clinical benefits of treating these injuries with IMNs led surgeons to make implant design modifications and improve surgical techniques to yield the results we have today with malalignment rates of less than 8% in several recent series.6,7

IMPLANT DESIGN

Some reasons for failure in treatment, defined by malalignment or loss of fixation, can be in part attributed to early implant design. Early generation tibial nails had a proximal sagittal bend (Herzog curve) that was larger than currently available nails, and/or had a bend that extended distal to the fracture site. Both of these design characteristics contribute to what Henley and coworkers8 referred to as the “wedge effect,” which occurs as the nail is seated and impinges on the posterior cortex of the distal segment accentuating an apex anterior deformity because of the effective widening of the nail above the bend and posterior force on the distal segment to match the nail shape.

Additional reasons for early fixation failure in these fractures have been attributed to use of a single proximal interlocking bolt, or use of the dynamic interlocking mode. Both Henley and coworkers8 and Laflamme9 demonstrated the problems associated with limited fixation in the proximal segment, and implant modifications to include additional oblique/multiplanar interlocking bolt options have minimized loss of fracture reduction.

Further modifications to IMN design have included the addition of angular stable locking screws that thread into the nail. Although they seem to offer additional stability, especially in osteoporotic bone, when compared with conventional implants (nonthreaded locking holes) using a biomechanical proximal tibia fracture model they offered no extra benefit.10

NAIL STARTING POINT

The starting point should be just medial to the lateral tibia spine on the anteroposterior (AP) fluoroscopic image (ensure appropriate rotation using the fibular bisector line or the “twin peaks” view) and just anterior to the articular surface on the lateral fluoroscopic image (“flat plateau”). Obtaining the correct starting point is important for nailing proximal tibia fractures for two reasons. First, just as in standard nailing for tibia fractures, the surgeon should avoid damage to the intra-articular structures. Tornetta and colleagues11 have detailed the safe zone for tibial nailing, which is 9.1 ± 5 mm lateral to midline of the plateau and 3 mm lateral to the center of the tubercle. The width averaged between 22.9 and 12.6 mm. A follow-up study was performed to identify the fluoroscopic images that correlate with the appropriate safe zone. Kirschner wires were placed in cadaveric knees under direct visualization of the safe zone, and then radiographs were obtained that demonstrated that the safe zone is just medial to the lateral tibial spine on the AP and just anterior to the articular surface on the lateral image. There was some variance on the AP, but no variance on the lateral image.12

A recent study confirmed the importance of obtaining appropriate intraoperative fluoroscopic images, because a slight external rotation of the proximal tibia when obtaining fluoroscopic images of the starting point can result in a misleading medial entry point, which may accentuate a valgus deformity. The authors of this study used the fibular bisector line (overlap of the lateral border of the tibia bisecting the fibula head) as a reliable intraoperative fluoroscopic confirmation of appropriate rotation because the entry point using this image was always either ideal or less than 5 mm lateral to the ideal entry point, but never medial.13 Because of the potential valgus deformity obtained with intramedullary nailing of proximal tibia fractures, avoidance of a medial starting point is paramount.

An alternative method for ensuring appropriate rotation on intraoperative fluoroscopic images is use of the twin peaks AP view and flat plateau lateral view.14 A cadaveric study demonstrated excellent intraobserver and interobserver reliability with use of this technique compared with use of the fibular bisecting line on the AP view and perfectly aligned femoral condyles on the lateral view, allowing for accurate identification of the starting point. The twin peaks AP view simply obtains the sharpest profile of the tibial spines and the flat plateau lateral view lines up the posterior aspect of the femoral condyles and then adds the limb to line up the medial and lateral tibial plateaus (Figs. 1 and 2).

NAILING TECHNIQUES

Nailing in Flexion

- Hyperflexion permits accurate guidewire placement and alignment in sagittal plane.
The incision can be medial, through, or lateral to the patellar tendon to facilitate accurate pin placement.

- Ensure trajectory of guidewire or awl is correct on intraoperative fluoroscopy before reaming the proximal tibia.
- Fracture must be reduced before canal preparation (reaming) and implant placement.
- Place locking bolts with limb in extension (the position of reduction).

The traditional method of nailing tibia fractures, regardless of location of the fracture, has been to nail in flexion. Hyperflexion of the knee allows accurate placement and alignment of the guidewire in the sagittal plane, nearly parallel to the anterior cortex. The incision is most commonly medial to the patellar tendon, but can be midline or even lateral to the tendon in certain cases to facilitate accurate pin placement and minimize interference from the extensor mechanism.\textsuperscript{15} After preparation of the entry portal, it is important to extend the knee for reduction, canal preparation, and placement of the interlocking bolts.\textsuperscript{4} This balances the deforming forces on the proximal tibia in the sagittal plane to assist in maintenance of reduction. However, it must be emphasized that the fracture should always be reduced before or while reaming and nailing, because simply extending the leg without using proper technique throughout the procedure does not compensate for the resultant deformity with nail passage. This point likely led to modifications to the implant system and surgical technique to accommodate nailing in the semi-extended position, making it easier to keep the fracture reduced while reaming and during passage of the IMN.

**Nailing in Semiextended Position**

- Limit flexion to approximately 15° to neutralize the force of the extensor mechanism on the knee.
proximal tibia leading to an apex anterior deformity, and to relax the tissues allowing for easier instrumentation in proper alignment. The slight flexion allows access to the proximal tibia to obtain the correct starting point.

- This can be done with small radiolucent bump or triangle behind the knee, which allows for slight flexion. In addition, the use of an elevated radiolucent leg ramp elevates the injured extremity above the contralateral leg, making intraoperative fluoroscopy easier (Figs. 3 and 4).
- The approach can be made medial or lateral to the patellar tendon depending on which way it is easier to subluxate the patella.
- Trochlear groove used as an alignment guide for instrumentation.
- Ensure trajectory of guidewire or awl is correct on intraoperative fluoroscopy before reaming the proximal tibia.
- Fracture must be reduced before canal preparation (reaming) and implant placement.

Tornetta and Collins$^{16}$ were one of the first to describe nailing proximal tibia fractures in the semiextended position with the use of an arthrotomy. Of 25 patients with proximal tibia fractures treated with IMNs by this technique, 19 had anatomic alignment in the sagittal plane, and none had greater than 5° malalignment in the sagittal plane. Two of the 25 had coronal plane deformities greater than 5°. In a prospective study, Vidyadhara and Sharath$^{17}$ had a 16% malunion rate in 7 of 45 patients with proximal tibia fractures treated with intramedullary nailing in the semiextended position, three in valgus and four apex anterior greater than 5°. Variations of this semiextended technique have been reported with the use of extra-articular approaches.$^{18,19}$

**Suprapatellar Nailing**

- Similar amount of knee flexion (15°) required as in semiextended to neutralize the force of the extensor mechanism on the proximal tibia leading to an apex anterior deformity. The slight flexion allows access to the proximal tibia to obtain the correct starting point.
  - An elevated radiolucent leg ramp is used to elevate the injured extremity above the contralateral leg, making intraoperative fluoroscopy easier.
  - A small radiolucent bump is required under the knee to obtain appropriate amount of knee flexion.
- Skin incision is approximately 2 cm in length, starting 2 cm above patella and extending proximally (Fig. 5).
- Quadriceps tendon is well visualized, with deep incision through its midsubstance, stopping 5 mm above superior patellar pole.

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Fig. 3. Use of a radiolucent ramp under the operative extremity aids in achieving slight knee flexion while elevating the operative extremity above the contralateral limb, making intraoperative fluoroscopy easier.

Fig. 4. A bump placed under the knee may be used to aid in obtaining optimal knee flexion to obtain the correct starting point.

Fig. 5. The skin incision is approximately 2 cm in length, starting 2 cm above the superior pole of the patella (outlined with the dark curvilinear line), mid axis.
• Finger palpation of the patellofemoral space to assess if adequate room for the trocar to be placed.
  ○ If more space is needed (ie, trocar does not fit or is very tight), determine which way the patella subluxates more freely and cut 1 to 2 cm of the patellar retinaculum medially or laterally to allow subluxation of the patella, leaving a cuff for later extensor mechanism repair.
• Ensure trocar/cannula placed down to tibia to ensure that the femoral condyles and patella are not damaged when instrumenting/reaming, or by the cannula edge with sliding.
• Systems may allow securing the cannula to the distal femur with a wire, which ensures cannula does not back out during the procedure putting condyles and patella at risk of damage by the reamer and cannula edge. If system does not have this feature, always ensure cannula pushed down at all times.
• Trochlear groove used as an alignment guide for instrumentation.
• Ensure trajectory of guidewire is correct on intraoperative fluoroscopy before reaming the proximal tibia.
• Fracture must be reduced before canal preparation (reaming) and implant placement.
• Systems may allow nail to be passed through cannula. Ensure that system does allow if desired, and size nail chosen will fit through the cannula because certain systems’ cannulas can only accommodate certain size nails.
• At the conclusion of the procedure, thoroughly irrigate knee and assess patellofemoral joint.

More recently, the suprapatellar or retropatellar approach has gained popularity because of the relative ease with which the appropriate starting point can be identified using the trochlear groove as a guide, and the ability to keep the leg in one position throughout reaming and nail insertion (Figs. 6 and 7). Even with this technique, the optimum amount of knee flexion remains somewhere around 15°, which allows for a more accurate placement of the initial guidewire in the safe zone at the appropriate insertion angle.\textsuperscript{16,20}

One of the initial concerns with suprapatellar nailing was caused by the thought that the contact pressures of the implants or instruments would be high enough to cause damage to the surrounding cartilage. In a study evaluating contact pressures using a modern nailing system that has a suprapatellar cannula, an increase in the mean pressure on the cartilaginous surfaces was found for suprapatellar compared with infrapatellar technique. However, suprapatellar technique had a mean of 1.84 MPa (range, 1.09–2.95 MPa) on the patella and 2.13 MPa (range, 1.10–2.86 MPa) on the femoral condyles, which is much lower than that which can impair the structural integrity of the cartilage with a single impact (>25 Mpa) and nearly half the pressures required to induce chondrocyte apoptosis with sustained loads (4.5 Mpa) in immature bovine cartilage.\textsuperscript{21}

Additionally, a recent cadaveric study demonstrated that another benefit to the retropatellar technique when compared with parapatellar nailing is a significant decrease in the damage to intra-articular structures, with a similarly sized resultant entry hole and anterior cortical damage in the proximal tibia.\textsuperscript{22} Whether this has any clinical significance has yet to be demonstrated.

Fig. 6. Intraoperative AP (A) and lateral (B) fluoroscopic images demonstrating the ease with which the correct starting point can be found and the ease with which alignment is maintained without much, if any, manipulation of the extremity during passage of the nail (C, D).
REDUCTION TECHNIQUES

Clamp-assisted Reduction

- Ensure safe passage of clamps when placed percutaneously, especially along the posterior border of the proximal tibia.
- Attention to soft tissue impingement is paramount with percutaneous clamp placement; if the tissues are compressed, alternative wider periarticular clamps may be helpful.
- Caution should be exercised when placing percutaneous clamps to reduce the flexion deformity seen in proximal tibia fractures by ensuring that the clamp remains in contact with the bone all the way around the posterior aspect of the proximal tibia. Attention to soft tissue impingement is paramount with percutaneous clamp placement because narrow pointed reduction forceps pinching the skin may cause tissue necrosis if left in place for even short amounts of time. If the tissues are compressed, alternative wider periarticular clamps may be helpful.

Blocking/Poller Screws

- Ideal time for blocking screw placement is before reaming and placing the nail.
  - Can also be placed later in the procedure to
    - Correct deformity with nail removal and rereaming.
    - To enhance construct stability in metaphyseal fracture with poor bone quality or comminution.
- If placing before reaming, the authors recommend using larger screws or the systems interlocking bolts, because smaller screws (≤3.5 mm) may bend or break under load caused by weakening if a portion of the screw.

Although not commonly described for proximal tibia fractures, the use of percutaneous clamps can be extremely effective in obtaining and maintaining reduction while reaming and during passage of the nail (Figs. 8 and 9). The use of percutaneous clamps has resulted in good outcomes in comminuted tibial shaft fractures and distal third tibia fractures.\(^{23,24}\) It is often easier to place clamps in open fractures because one can directly visualize clamp placement; however, they can also be effectively used in closed injuries through stab incisions. Caution should be exercised when placing percutaneous clamps to...
is reamed. Do not use a drill bit as a blocking pin because they can be brittle and break. Can also consider a 3.2-mm (more flexible) or larger Steinman pin, which can be removed after locking the nail (the “stealth” blocking screw).

• Several nailing systems have targeters for placing blocking screws.
• Beware of fracture propagation and watch carefully under fluoroscopy. Consider placing the blocking screws at least 1 cm away from fracture to minimize risk.

Fig. 8. Intraoperative lateral fluoroscopic view demonstrating apex anterior deformity with a segmental proximal tibia fracture after nail passage (using suprapatellar technique), even with a temporary plate used to assist with alignment of the proximal fracture (A). Addition of a blocking screw and clamp-assisted reduction resulted in improved alignment in the coronal plane (B, C).

Fig. 9. Postoperative AP (A) and lateral (B) radiographs of the patient shown in Fig. 8, demonstrating appropriate final alignment. Note that the temporary plate shown in Fig. 8 was removed after locking the nail.
Because of the cavernous proximal tibia and the typical deformity associated with proximal tibia fractures, blocking screws, also referred to as Poller screws, have been used to decrease the effective size of the proximal tibia, thus controlling the IMN path in the proximal tibia and helping to mitigate potential malalignment. Blocking screws are always placed on the concavity of the deformity. For proximal tibia fractures, which have a typical apex anterior and valgus deformity, the blocking screws can be placed lateral and/or posterior to the nail in the proximal segment. Figs. 10–16 demonstrate simulated and clinical application of blocking screws. Krettek and colleagues also demonstrated that, in addition to improving and maintaining alignment, blocking screws offer a biomechanical advantage when used in the treatment of proximal tibia fractures because they increase the overall bone-implant-construct stability. Therefore, consideration may be given in certain cases (osteoporosis, comminution) to adding Poller screws to enhance construct stability, even if they were not required to obtain alignment.

Good success in obtaining and maintaining alignment using blocking screws has been demonstrated in several clinical series. Ricci and coworkers reported on 12 consecutive patients and only had one postoperative malalignment of 6° of valgus that progressed to 10° at final follow-up; however, in this case, no blocking screws were used. In all other cases, the fractures healed with no clinical malalignment. The use of blocking screws can generate significant forces so the surgeon should beware of fracture propagation and watch carefully under fluoroscopy during each step. Consideration should be given to placing the blocking screws at least 1 cm away from fracture to minimize risk, because fracture propagation can lead to either construct instability with metadiaphyseal extension or articular incongruity with proximal fracture extension.

**Plate-assisted Reduction**

- Use a 3.5-mm dynamic compression plate (DCP) or limited contact dynamic compression plate (LC-DCP), five- or six-hole plate with minimum of two screws on both sides of the fracture. Less stout implants or points of fixation can lead to loosening during nail implantation and subsequent loss of reduction.
- Use unicortical screws or place bicortical outside the projected path of the nail.
- Remove plate after locking the nail, or leave in place, with possible exchange of unicortical screws for bicortical screws.
- Although this technique is often reserved for open fractures, it can be considered for closed fractures when alignment cannot be obtained or maintained with other techniques.

One of the difficulties with proximal tibia fractures is not just obtaining a reduction, but maintaining it...
while reaming and placing the implant. A provisional plate can be added to assist in obtaining and maintain reduction, more commonly done in open fractures because the tibia has already been exposed for debridement, but also in select closed fractures when other closed and percutaneous methods are unsuccessful. Several studies have reported good results using this technique.

Fig. 11. The valgus deformity seen in Fig. 10 has been corrected with placement of a lateral blocking screw in the proximal segment.

Fig. 12. The typical apex anterior (procurvatum) deformity present after nail insertion for a proximal tibia fracture is shown.
Because of the amount of force that can be transmitted when placing an IMN, the authors recommend using a 3.5-mm DCP or LC-DCP plate. Using a less stout plate (ie, one-third tubular plate) can result in loss of reduction and bending of the plate during nail passage (personal experience). Typically, only a five- or six-hole plate is all that is necessary. Screws are either placed

Fig. 13. The apex anterior (procurvatum) deformity seen in Fig. 12 has been corrected with placement of a posterior blocking screw in the proximal segment.

Fig. 14. (A, B) Radiographs demonstrating a healed tibia fracture with appropriate alignment achieved with use of blocking screws, both in the sagittal and coronal plane, in addition to the use of plate-assisted reduction, which was left in place.
Fig. 15. Fluoroscopic image demonstrating typical valgus deformity after locking the nail proximally. Of note, the patient had a segmental tibia fracture and the proximal fracture was not recognized until fluoroscopic imaging obtained to check proximal locking bolt lengths (A). The nail was subsequently removed and blocking screws added, two in the sagittal plane and one in the coronal plane, followed by rereaming and nail placement (B).

Fig. 16. Postoperative AP (A) and lateral (B) radiographs demonstrate improved final alignment of the patient shown in Fig. 15 after the addition of blocking screws to aid in reduction of the proximal tibia fracture.
unicortically or bicortically directed around the anticipated nail path. The plating should be performed with no iatrogenic periosteal stripping. After the nail is passed and interlocking bolts placed, the plate can be removed, left in place with unicortical screws, or left in place with screws exchanged for bicortical screws around the nail (see Figs. 8, 9, and 14).6,7,26

Dunbar and colleagues7 performed provisional plating in 31 fractures, removing the plate after the nail was locked. In 18 patients the alignment remained anatomic and in the other 13, there was less than 3° of malalignment. Nork and colleagues6 used plate-assisted reduction in 13 proximal quartile extra-articular tibia fractures. Three plates were temporary and removed after placing the IMN, and in the other 10 cases, the unicortical screws were exchanged for bicortical screws after the locking screws were placed. In this series, other techniques were also used to include the use of a femoral distractor, with acceptable alignment (<5° malalignment) obtained in 34 (92%) of 37 fractures, two with 5° malalignment and one with 7° malalignment.

**Universal Distractor**

- A medially based universal distractor can be used to correct multiplanar deformity.
- Consider placing the proximal Schanz pin in a manner that would act as a blocking screw to prevent an apex anterior deformity.
- Ensure placement of distal Schanz pin is out of (or distal to) the anticipated trajectory of the nail.

In the study by Nork and colleagues6 describing their outcomes on proximal quartile tibia fractures treated with an IMN, a medial distractor was placed in 68% of cases. It can be applied medially to counteract the valgus deformity by “dialing in” the coronal alignment. Although no blocking screws were using in this study, the proximal Schanz pin for the distractor was placed in a manner to behave like a blocking screw. In that study, 34 of 37 fractures had less than 5° angular deformity, 2 had 5° (coronal), 1 had 7° (coronal).

Wysocki and colleagues29 modified this technique using a two-pin fixator construct. The authors described using 2- to 5-mm centrally threaded transfixion pins connected to carbon fiber rods medially and laterally creating a form of traveling traction that can aid in fracture reduction. The authors also used “strategic placement of a bump” to aid in correction of sagittal plane deformity. Using this technique on 15 proximal and distal tibia fractures, the authors reported 14 with angular deformity less than 5°.

**SUMMARY**

Despite poor early results with intramedullary nailing of extra-articular proximal tibia fractures, improvements in surgical technique and implant design modifications have resulted in more acceptable outcomes. However, prevention of the commonly encountered apex anterior and/or valgus deformities remains a challenge when treating these injuries. It is necessary for the surgeon to recognize this and know how to neutralize these forces. Surgeons should be comfortable using a variety of the reduction techniques presented to minimize fracture malalignment.

**REFERENCES**


