Problems, Tricks, and Pearls in Intramedullary Nailing of Proximal Third Tibial Fractures

Frank A. Liporace, MD, Christopher M. Stadler, BS,* and Richard S. Yoon, MD†*

Summary: Proximal third tibial shaft fractures have been notoriously difficult to treat. Early reports resulting in high rates of malunion and fixation failure trended surgeons to move away from intramedullary nailing as definitive treatment. However, with the advent of a deepened understanding of the surround anatomy, several techniques have been developed to help maintain proper alignment without early failure or malunion. This review provides a concise update on the tips, tricks, and pearls available in achieving a stable well-aligned construct when definitively treating proximal third tibial shaft fractures via intramedullary nail.

Key Words: intramedullary nail, proximal third, tibia fracture, tips, tricks, techniques, percutaneous plate

Level of Evidence: Therapeutic Level V. See Instructions for Authors for a complete description of levels of evidence.

(*J Orthop Trauma* 2013;27:56–62)

INTRODUCTION

Although intramedullary nailing (IMN) has arguably become the operative standard for the majority of femoral and tibial shaft fractures, controversy still remains regarding the definitive management for proximal third tibial fractures.[1–7] Historically, proximal third tibial fractures have been notoriously difficult to fix and maintain proper alignment without early failure in reported series.[5–18] Regarding IMN, specifically, malunion rates have been reported to be as high as 84%.[19] Furthermore, several earlier series offered subpar rates of fracture failure, typically into an apex anterior and valgus position.[20,21]

These early poor results led to surgeons trending away from the use of IMN for proximal third tibial fractures. However, with continued research furthering the understanding of the specific anatomy and deforming forces surrounding the proximal third of the tibia along with the potential benefits of early weight-bearing and decreased soft tissue trauma, a recent renewed resurgence of IMN usage for proximal third tibial shaft fractures has been observed.[12,22,23] Understanding these concepts allowed for several effective techniques, tips, and tricks to help maintain reduction and restore native anatomy leading to recent studies exhibiting high rates of union and low resultant deformities after IMN.[24–27] This state of the art review outlines the latest update in technical tricks and management pearls available for treating proximal third tibial shaft fractures via IMN along with the associated pros and cons.

Accepted for publication February 17, 2012.
From the *Division of Orthopaedic Trauma, Department of Orthopaedic Surgery, UMDNJ—New Jersey Medical School, Newark, NJ; and †Department of Orthopaedic Surgery, NYU Hospital for Joint Diseases, New York, NY.
The authors report no conflicts of interest.
Reprints: Frank A. Liporace, MD, Division of Orthopaedic Trauma, Department of Orthopaedic Surgery, UMDNJ—New Jersey Medical School, 90 Bergen St, Suite 1200, Newark, NJ 07101 (e-mail: liporace33@gmail.com).

WHY DO IMN OF PROXIMAL THIRD TIBIAL SHAFT FRACTURES FAIL?

The natural bony anatomy and muscular attachments of the proximal tibia offers the perfect set up for a number of common deformities after fracture with subsequent malalignment during IMN placement. Muscular stresses via tendinous attachments contribute considerably to producing these deformations.[23] The dynamic forces via the patellar tendon pull the proximal fragment into an apex anterior angulation, whereas the attachment of the pes anserinus commonly causes valgus stress on the same fragment.[20,21] Before operative fixation, these forces create the potential for improper reduction and difficult reaming and suboptimal nail placement. During operative nailing of proximal fractures with the knee in hyperflexion, the patellar tendon again draws the proximal fragment into a procurvatum deformity.[23] Lang et al[21] demonstrated poor results with conventional techniques for IMN of proximal third tibial fractures: 84% with >5-degree frontal or sagittal plane deformity; 59% with 1 cm or greater displacement; 25% with loss of fixation; 28% required exchange nailing. In part, these undesirable results have been attributed to the dynamic deforming forces of the natural anatomy.

CONSIDERATIONS FOR IMN—GOALS OF FIXATION AND UNDERSTANDING ANATOMY

The goals of proximal third tibial fracture fixation are to restore native anatomy in terms of mechanical axis, length, rotation, and alignment. Conventional goals for alignment can be defined as ≤5 degrees of varus/valgus deformity, ≤10 degrees of flexion or extension, ≤10-degree malrotation, and <1 cm of shortening. Early studies have allowed as much as 12 mm of shortening as long as proper alignment is obtained.[28] Attainment of these numbers with the appropriate fixation via IMN allows for rapid healing, early range of motion, and avoidance of complications such as joint pain and degenerative joint disease.[1,8,9,11,14,24]

Intimate anatomic knowledge of the tibial intramedullary canal is critical for proper nail placement. The canal of the tibia is widest in diameter in the metadiaphysis offering the least purchase for fracture reduction with IM nails.[12,22]

The canal itself originates 4 cm distal to the tibial tubercle and its central axis is situated lateral to the center of the tibial plateau.[12,22] These anatomic considerations have led to the establishment of a standard "safe zone" for the starting point for intramedullary nails of the tibia.[12,22] This "safe zone" is defined as the area proximal to the tibial tubercle and anterior to the articular surface, which includes the intermeniscal ligament and menisci. Numerically, this turns out to be 9 mm lateral to midline, and a mere 23 mm wide.[22,29] In essence, a proper starting point for tibial IMN lies lateral to the midline and anterior to the joint surface, near the medial border of the lateral tibial spine on the anteroposterior (AP) radiograph and at the anterior border of the juncture of the anterior surface of the tibia and the articular surface on the lateral radiograph (Figs. 1A, B).[22]

Any deviation from this safe zone is likely to increase the difficulty of nail insertion and contribute to translational and angular deformities. Nail start hole penetration below this zone is risky for posterior cortical penetration and may contribute to further eccentric reaming that can put the extensor mechanism at jeopardy. Nail insertion above this area will cause damage to articular surfaces, anterior horn of the menisci, or intermeniscal ligament. Key points to consider here include the following: (1) lateralizing the entry hole for nail placement, (2) keeping the entry hole anterior to the articular margin, and (3) insertion angles in the sagittal plane as near to parallel to the anterior cortex as possible (Table 1). These points maximize the sagittal diameter of the canal by entering at its widest point and correspond with the defined safe zone.[22] A laterally placed entry hole has also been shown to prevent injury to the patellar tendon and anteromedial tibial cortex and help counter valgus deformity in the coronal plane.[22] Buehler et al[23] verified this anatomy with an average anterior displacement of 3.0 mm and 2 degrees of valgus deformity using a lateralized starting hole for IM nail placement in proximal third tibial fractures. An insertion vector in the sagittal plane that is parallel to the anterior cortex has been shown to minimize extension forces on the proximal fragment, thus reducing apex anterior deformity.[2,21,26] An insertion angle aimed too posteriorly can accentuate an angular deformity of the proximal fragment in the sagittal plane as well as possibly penetrating the posterior cortex. However, a start site too far anteriorly may disrupt the anterior tibial cortex and offer no reduction for anterior angulation.

SURGICAL OPTIONS AND TECHNIQUES TO MAXIMIZE OUTCOME AFTER IMN

Several techniques and pearls have been developed to aid in achieving well-aligned stable reconstruction via IMN after proximal third tibial shaft fracture (Table 2). Here, we review each technique and the supporting results available in the literature.

Nailing in Extension

With the knee in extension, the deforming forces transmitted through the patellar tendon are neutralized, allowing easier reduction and nail placement. In the literature, a few different approaches have been described.[25–27,30] Tornetta et al[25] nailed 25 proximal tibia fractures with the knee in 15 degrees of flexion. Using a medial parapatellar approach and laterally subluxating the patella, the trochlear groove was used as a conduit for a straight awl to create the start hole. Results were encouraging with none of these patients having more than 5 degrees of anterior angulation and 19 of them with no anterior angulation at all. Only 2 of these patients had angulation greater than 5 degrees in the coronal plane.

A suprapatellar/retropatellar technique has recently been shown to minimize soft tissue dissection. In this approach, the nail is inserted proximal to the superior pole of the patella through a longitudinal incision in the quadriceps tendon (Figs. 2A–C). This approach was successful in achieving an anatomically safe starting hole and optimizing sagittal plane insertion angles for proximal fractures.[26] This study had optimum results at knee flexion angles between 20 and 50 degrees. A flexion angle of 50 degrees was found to provide best access to the safe zone for nail insertion while still keeping patellar tendon deforming forces at a minimum. Eastman

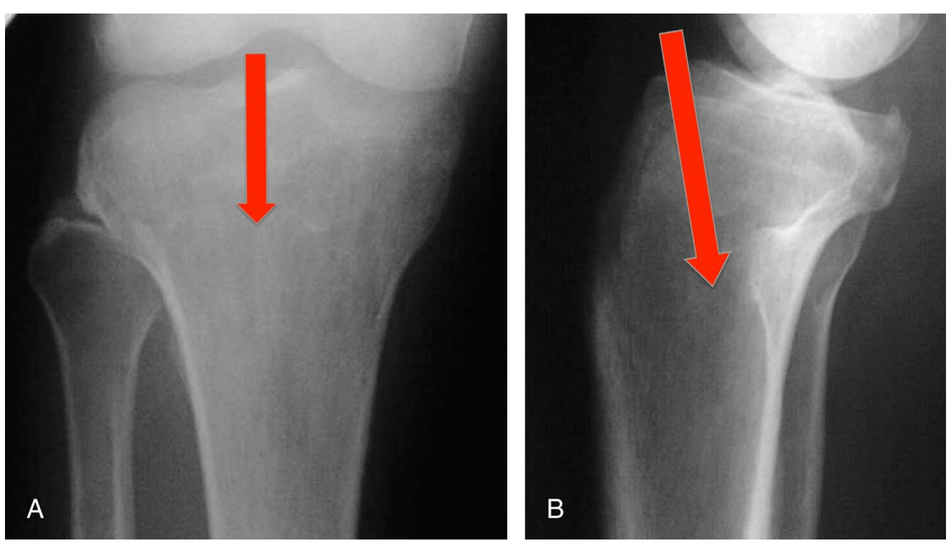

FIGURE 1. Optimal starting point in (A) AP and (B) lateral views for proximal third tibial shaft fractures.

TABLE 1. Key Points Regarding Entry Portal for IMN of Proximal Third Tibial Shaft Fractures

Lateralize entry hole
Keep entry hole anterior to the articular margin
Sagittal plane insertion angle as near to parallel to the anterior cortex as possible

et al[26] confirmed the moderate degree of knee flexion (20–50 degrees) needed to allow for nail insertion angles in sagittal plane that were nearly parallel to the anterior cortex. This vector is crucial for reducing the anterior angulation deformities and may also be helpful for fractures with posterior comminution.[2,21,26] Also, external fixators or femoral distractors can be incorporated with this technique to allow for maintenance of length.

Of concern here is damage to the articular surfaces through which the nail must pass, that is, the patella and femoral condyles. At a threshold of 4.5 MPa, articular cartilage has been shown to undergo apoptosis. In one cadaveric study, it was shown that the passage of IMN across the surfaces of the patella and femoral condyles using this suprapatellar technique did not, in fact, generate a force great enough to induce apoptosis.[30] Also, when utilizing this technique, consideration must be given to using a nail with specialized instrumentation to allow for an appropriately sized metallic cannula for guidewire insertion, reaming, and so on. When using nonmetallic cannulas, potential cannula fraying can lead to intraarticular foreign bodies and third body wear.

Kubiak et al[27] demonstrated an extraarticular modification to the semi-extended parapatellar technique for the successful stabilization of proximal tibial fractures. In this technique, the patella is medially or laterally subluxated, depending on which direction the patella's natural laxity tends toward. Reaming, guide wire, and nail manipulation is performed through this passage. This method follows the guide of the standard anatomic models of the proximal tibia while avoiding damage to the synovium and trochlea.[27]

Femoral Distractor and External Fixation

There are 2 similar techniques that can be used to apply indirect reduction to set the stage for successful IMN in proximal tibia fractures: use of a femoral distractor or an external fixator. Nork et al[14] used a femoral distractor for length maintenance and alignment during reamed IMN of proximal fractures. Overall, the study achieved 92% acceptable alignment. Other techniques were used in combination with the distractor. These included unicortical plating (n = 13), percutaneous clamping (n = 7), and manipulation with Schanz pins (n = 4).[14] These results attest to both the successful use of femoral distractors alone and the possibility of successful

TABLE 2. Surgical Options for IMN in Proximal Third Tibial Shaft Fractures

Extended/semi-extended nailing
Median parapatellar[25]
Suprapatellar/retropatellar[26,30]
Extra-articular[27]
Femoral distractor/external fixation
Poller/blocking screws
Supplemental provisional or permanent plate fixation

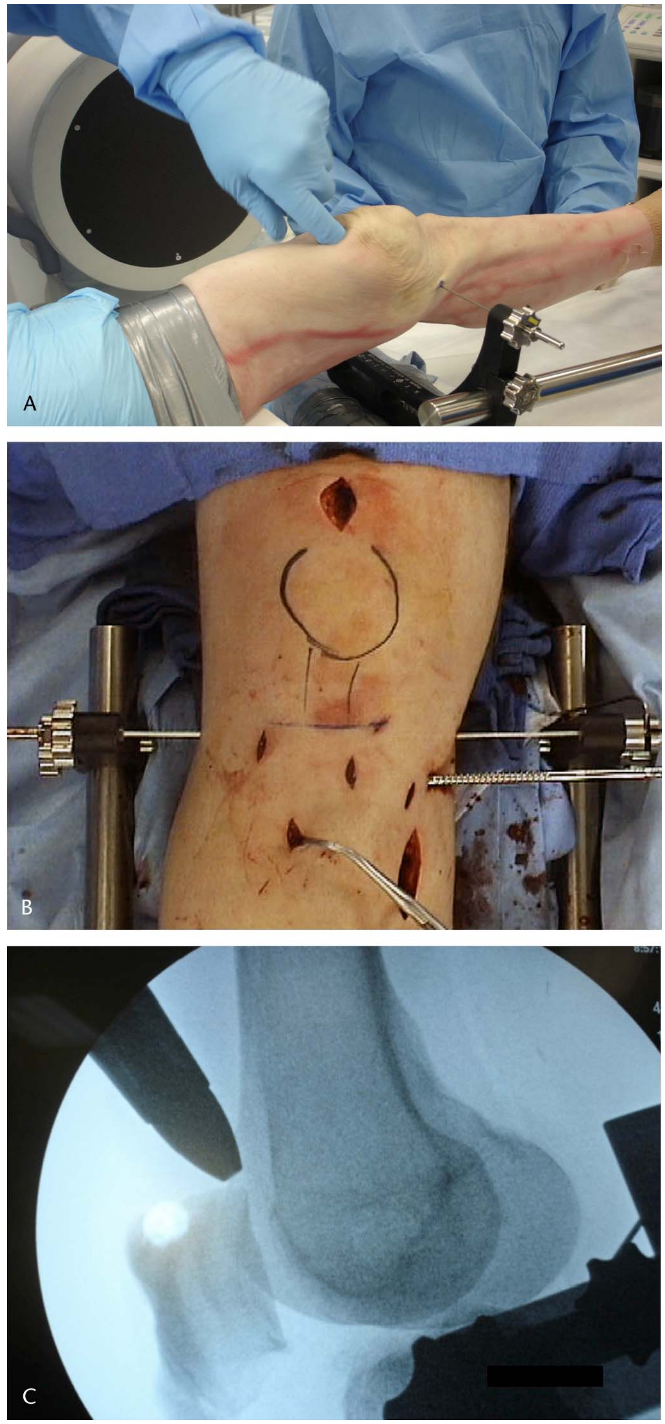

FIGURE 2. A–C, Suprapatellar nailing of the tibia uses a semi-extended position of the knee with nail insertion through the quadriceps tendon (photographs courtesy of Thomas DiPasquale, DO).

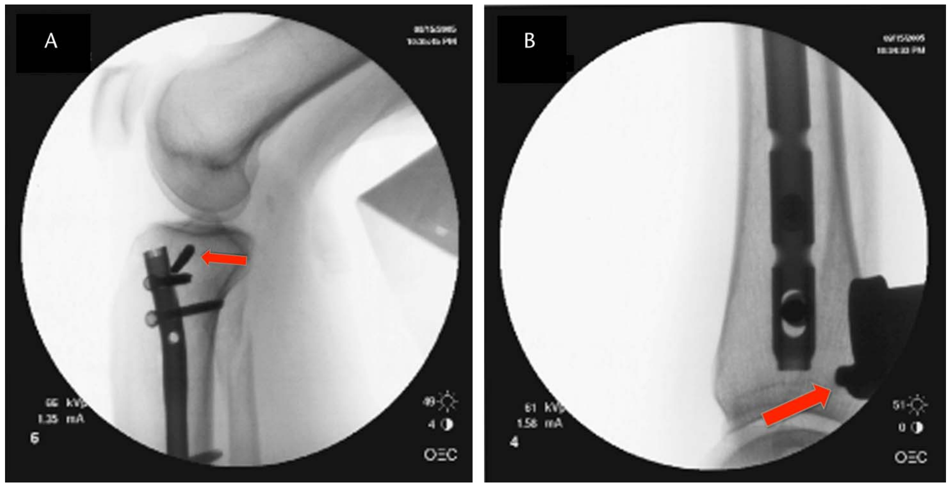

FIGURE 3. Proper placement of the Schanz pins (A) proximally and (B) distally should allow for facile passage of the nail (arrows). Proximally, the pin must be placed with cognizant knowledge of the peroneal nerve (arrow).

fixation for proximal tibia fractures using varied techniques. Furthermore, a focused study examining the use and the technique of utilizing an external fixator in a similar fashion has not been described in the literature, but one can imagine the similarities and aide it can provide in maintaining alignment and reduction during reaming and IMN placement during fracture reconstruction.

The distractor or fixator Schanz pin can be placed in the proximal and distal tibia, posterior to the tract of the ultimate nail. Proximally, it must be anterior to the course of the peroneal nerve. The Herzog curve of the nail should allow for nail passage in the proximal fragment, even with the Schanz pin in place (Figs. 3A, B). Also, both pins should be parallel to the plateau and pilon, respectively. Because the distraction force is posterior to the midaxial line of the tibia, lengthening of the concavity of the procurvatum deformity will occur to allow for restoration of the mechanical axis. Similarly, lateral or medial placement or "dueling fixators" can be applied to counter coronal plane deformity.

Blocking/Poller Screws

Blocking or Poller screws and drill bits can be inserted in the coronal and sagittal planes to functionally decrease the width of the wide metaphyseal medullary canal (Figs. 4A–D).[15,31,32] This ensures that the IMN follows the native anatomy of the canal, thus maintaining crucial stabilizing contact with the tibial cortex. In a biomechanical study with interlocked IM nails for proximal tibial fracture fixation, Krettek et al[31,32] have shown that placement of medial and lateral blocking screws in the anterior–posterior plane decreased the rate of deformation by 25% ($P < 0.0001$) compared with interlocked IM nails without blocking screws. The

FIGURE 4. Preoperative (A) AP and (B) lateral radiographs of a proximal third tibial shaft fracture that was definitively treated with IMN in combination with blocking screws (arrows; C and D).

FIGURE 5. Intraoperative photo showing minimal soft tissue stripping with percutaneous plate placement when using IMN and plate combination for proximal third tibial shaft fractures.

blocking screws placed in the AP plane were meant to augment the stability of the nail which was interlocked with two transverse and one AP locking screw. Ricci et al[15] had similar success when combining blocking screws with IM nails. The placement of blocking screws in this study takes a systematic approach for correction of specific deformities—for example, to correct anterior angulation, screws were placed posterior to the central axis in the sagittal plane so that the nail would pass anterior to the screw, abutting the anterior cortex; for valgus deformity, screws were inserted lateral to the central axis in the coronal plane, allowing the nail to pass medially; and for varus angles, the screws were placed medial to the central axis, driving the nail against the lateral cortex. None of the patients had more than 5 degrees of angulation in the sagittal or coronal planes.[15]

Nork et al[14] showed an opportunistic use of blocking screws when the proximal Schanz pin in a femoral distractor was used as a blocking screw to direct nail placement. A great deal of force is exerted on blocking screws when directing IMNs through the medullary canal. This is the very nature of their functionality, but some caveats must be considered—osteoporotic bone, gunshot wounds, and occult fracture lines may not hold up to the forces transmitted through this hardware.

Supplemental Plate Fixation

Another option in the armamentarium when attempting to achieve stable, well-aligned fixation after IMN of proximal third tibial shaft fractures is the use of supplemental plate fixation. Dunbar et al[33] first described the technical trick in Gustilo and Anderson Type III open fractures, utilizing a provisional plate to secure the proximal fracture before IMN. Utilizing 3.5-mm dynamic compression or limited contact dynamic compression plating with unicortical screws, all 31 patients achieved anatomic alignment after the IMN and provisional plate combination.[33] Complications often related to high-grade open fractures were present, but in numbers comparable with the literature.[34,35] As a subset of a larger tibial IMN retrospective clinical paper, Nork et al[14] reported the use of provisional or permanent supplemental plate with IMN in open and closed proximal tibial fractures. Although the authors did not break down complications and alignment by specific technique, overall acceptable alignment was achieved in approximately 92% of the study cohort at a mean 19-month follow-up period.[14]

Plating of open fractures of proximal tibia for IM nail preparation allows one to avoid displacement of minimally displaced or as yet nondisplaced fragments. Plates may also be useful in situations where techniques like blocking screws are contraindicated, such as osteoporosis, severe comminution, articular extension, and so on. Furthermore, supplemental plate fixation can be used during closed fractures with minimal soft tissue stripping and maceration via percutaneous placement (Fig. 5). Depending on the fracture pattern, optimal plate placement can also possibly facilitate placement of the IMN locking screw through the plate and through the nail, creating a theoretically stiffer, unified rigid construct (Fig. 6).

When the plate is chosen, soft tissue considerations and fracture pattern dictate if it is applied medially or laterally, percutaneously. Very flexible fixation should be used for the

FIGURE 6. Theoretically increased stiffness can be obtained if the locking screw is placed through the plate and through the nail (arrow).

metadiaphyseal zone of fixation to avoid impeding secondary bone healing. Limited screw fixation and unicortical screws should be considered. Provisionally, bicortical screw fixation can aid with indirect reduction to the plate, but ultimately exchange for more "controlled instability" should be considered. Such limited fixation can also help avoid late instability in the severely osteoporotic patients (Figs. 7A–E). This technique seems reliable in helping to achieve and maintain proper reconstruction.[33,36] However, larger series are limited in the literature to definitively determine the true efficacy of this seemingly useful technical trick to achieve and maintain anatomic alignment.

CONCLUSIONS

In summary, although proximal third tibial shaft fractures have historically produced suboptimal results with IMN treatment, recent research has led to the development of several techniques and pearls resulting in more promising results in achieving stable well-aligned reconstruction. Deepened understanding of proximal tibial anatomy has provided the ideal lateral entry portal, whereas the use of external fixators, femoral distractors, and varied approaches to nailing in an extended or semi-extended position have offered promising clinical results. Furthermore, taking advantage of additional screws in a blocking fashion or additional provisional or permanent plates have exhibited yet another method to achieve anatomic alignment without the typical apex anterior and valgus fixation failure seen in the past. However, with the literature largely consisting of retrospective, level IV evidence, larger prospective trials will be needed to definitively assess the ideal treatment protocol for this notoriously difficult-to-treat fracture pattern cohort.

FIGURE 7. A–E, Intramedullary nailing combined with plate fixation can be especially helpful in reconstruction in patients with severely osteoporotic bone.

REFERENCES

1. Bhandari M, Guyatt G, Tornetta P III, et al. Study to prospectively evaluate reamed intramedually nails in patients with tibial fractures (S.P.R.I.N.T.): study rationale and design. *BMC Musculoskelet Disord*. 2008;9:91.
2. Bono CM, Levine RG, Rao JP, et al. Nonarticular proximal tibia fractures: treatment options and decision making. *J Am Acad Orthop Surg*. 2001;9:176–186.
3. Henley MB, Chapman JR, Agel J, et al. Treatment of type II, IIIA, and IIIB open fractures of the tibial shaft: a prospective comparison of unreamed interlocking intramedullary nails and half-pin external fixators. *J Orthop Trauma*. 1998;12:1–7.
4. Hooper GJ, Keddell RG, Penny ID. Conservative management or closed nailing for tibial shaft fractures. A randomised prospective trial. *J Bone Joint Surg Br*. 1991;73:83–85.
5. Keating JF, O'Brien PI, Blachut PA, et al. Reamed interlocking intramedullary nailing of open fractures of the tibia. *Clin Orthop Relat Res*. 1997; 338):182–191.
6. Keating JF, O'Brien PJ, Blachut PA, et al. Locking intramedullary nailing with and without reaming for open fractures of the tibial shaft. A prospective, randomized study. *J Bone Joint Surg Am*. 1997;79:334–341.
7. Littenberg B, Weinstein LP, McCarren M, et al. Closed fractures of the tibial shaft. A meta-analysis of three methods of treatment. *J Bone Joint Surg Am*. 1998;80:174–183.
8. Anglen JO, Blue JM. A comparison of reamed and unreamed nailing of the tibia. *J Trauma*. 1995;39:351–355.
9. Brumback RJ, Toal TR Jr, Murphy-Zane MS, et al. Immediate weight-bearing after treatment of a comminuted fracture of the femoral shaft with a statically locked intramedullary nail. *J Bone Joint Surg Am*. 1999;81: 1538–1544.
10. 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;18:528–535.
11. Egol KA, Tejwani NC, Capla EL, et al. Staged management of high-energy proximal tibia fractures (OTA types 41): the results of a prospective, standardized protocol. *J Orthop Trauma*. 2005;19:448–455; discussion 456.
12. Hicks CA, Noble P, Tullos H. The anatomy of the tibial intramedullary canal. *Clin Orthop Relat Res*. 1995; 321):111–116.
13. Matthews DE, McGuire R, Freeland AE. Anterior unicortical buttress plating in conjunction with an unreamed interlocking intramedullary nail for treatment of very proximal tibial diaphyseal fractures. *Orthopedics*. 1997;20:647–648.
14. Nork SE, Barei DP, Schildhauer TA, et al. Intramedullary nailing of proximal quarter tibial fractures. *J Orthop Trauma*. 2006;20:523–528.
15. Ricci WM, O'Boyle M, Borrelli J, et al. Fractures of the proximal third of the tibial shaft treated with intramedullary nails and blocking screws. *J Orthop Trauma*. 2001;15:264–270.
16. Ricci WM, Rudzki JR, Borrelli J Jr. Treatment of complex proximal tibia fractures with the less invasive skeletal stabilization system. *J Orthop Trauma*. 2004;18:521–527.
17. Schutz M, Kaab MJ, Haas N. Stabilization of proximal tibial fractures with the LIS-System: early clinical experience in Berlin. *Injury*. 2003;34 (suppl 1):A30–A35.
18. Stannard JP, Wilson TC, Volgas DA, et al. Fracture stabilization of proximal tibial fractures with the proximal tibial LISS: early experience in Birmingham, Alabama (USA). *Injury*. 2003;34(suppl 1):A36–A42.
19. Cannada LK, Anglen JO, Archdeacon MT, et al. Avoiding complications in the care of fractures of the tibia. *J Bone Joint Surg Am*. 2008;90: 1760–1768.
20. Williams J, Gibbons M, Trundle H, et al. Complications of nailing in closed tibial fractures. *J Orthop Trauma*. 1995;9:476–481.
21. Lang GJ, Cohen BE, Bosse MJ, et al. Proximal third tibial shaft fractures. Should they be nailed? *Clin Orthop Relat Res*. 1995; 315):64–74.
22. McConnell T, Tornetta P III, Tilzey J, et al. Tibial portal placement: the radiographic correlate of the anatomic safe zone. *J Orthop Trauma*. 2001;15:207–209.
23. Buehler KC, Green J, Woll TS, et al. A technique for intramedullary nailing of proximal third tibia fractures. *J Orthop Trauma*. 1997;11: 218–223.
24. Lindvall E, Sanders R, Dipasquale T, et al. Intramedullary nailing versus percutaneous locked plating of extra-articular proximal tibial fractures: comparison of 56 cases. *J Orthop Trauma*. 2009;23:485–492.
25. Tornetta P III, Collins E. Semiextended position of intramedullary nailing of the proximal tibia. *Clin Orthop Relat Res*. 1996; 328):185–189.
26. Eastman J, Tseng S, Lo E, et al. Retropatellar technique for intramedullary nailing of proximal tibia fractures: a cadaveric assessment. *J Orthop Trauma*. 2010;24:672–676.
27. Kubiak EN, Widmer BJ, Horwitz DS. Extra-articular technique for semi-extended tibial nailing. *J Orthop Trauma*. 2010;24:704–708.
28. Sarmiento A. A functional below-the-knee cast for tibial fractures. *J Bone Joint Surg Am*. 1967;49:855–875.
29. Tornetta P III, Riina J, Geller J, et al. Intraarticular anatomic risks of tibial nailing. *J Orthop Trauma*. 1999;13:247–251.
30. Gelbke MK, Coombs D, Powell S, et al. Suprapatellar versus infrapatellar intramedullary nail insertion of the tibia: a cadaveric model for comparison of patellofemoral contact pressures and forces. *J Orthop Trauma*. 2010;24:665–671.
31. Krettek C, Miclau T, Schandelmaier P, et al. 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;13:550–553.
32. Krettek C, Stephan C, Schandelmaier P, et al. The use of Poller screws as blocking screws in stabilising tibial fractures treated with small diameter intramedullary nails. *J Bone Joint Surg Br*. 1999;81:963–968.
33. Dunbar RP, Nork SE, Barei DP, et al. Provisional plating of Type III open tibia fractures prior to intramedullary nailing. *J Orthop Trauma*. 2005;19:412–414.
34. Court-Brown CM, Keating JF, McQueen MM. Infection after intramedullary nailing of the tibia. Incidence and protocol for management. *J Bone Joint Surg Br*. 1992;74:770–774.
35. Court-Brown CM. Reamed intramedullary tibial nailing: an overview and analysis of 1106 cases. *J Orthop Trauma*. 2004;18:96–101.
36. Kubiak EN, Camuso MR, Barei DP, et al. Operative treatment of ipsilateral noncontiguous unicondylar tibial plateau and shaft fractures: combining plates and nails. *J Orthop Trauma*. 2008;22:560–565.

