Instructional Course Lecture

Controversies in the Intramedullary Nailing of Proximal and Distal Tibia Fractures

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Abstract

Management of tibia fractures by internal fixation, particularly intramedullary nails, has become the standard for diaphyseal fractures. However, for metaphyseal fractures or those at the metaphyseal-diaphyseal junction, choice of fixation device and technique is controversial. For distal tibia fractures, nailing and plating techniques may be used, the primary goal of each being to achieve acceptable alignment with minimal complications. Different techniques for reduction of these fractures are available and can be applied with either fixation device. Overall outcomes appear to be nearly equivalent, with minor differences in complications. Proximal tibia fractures can be fixed using nailing, which is associated with deformity of the proximal short segment. A newer technique—suprapatellar nailing—may minimize these problems, and use of this method has been increasing in trauma centers. However, most of the data are still largely based on case series.

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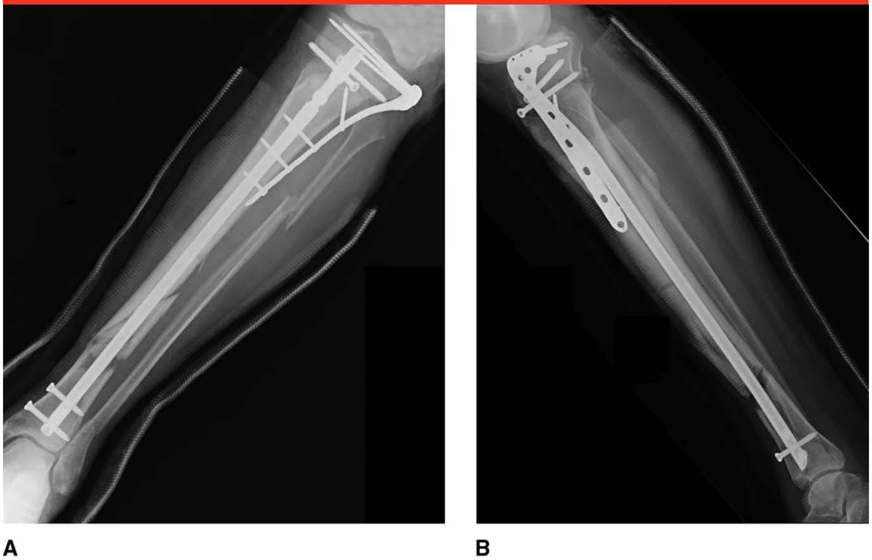
Fractures of the tibia are common and historically have been treated with casting and functional bracing. Because of the availability of newer implants and techniques for fracture fixation, surgical management has increased over the past few decades. The primary goal in the management of tibial fractures is to achieve acceptable alignment with minimal complications and allow early mobilization of the patient until healing has occurred.

The use of intramedullary (IM) nails has become the standard of care for tibial shaft fractures. However, proximal or distal metaphyseal fractures, with or without extension into the articular surface, can be treated in a variety of ways, including nailing, plating, and the use of external fixators. Similarly, open fractures or those with significant soft-tissue loss may require the use of nontraditional techniques or implants.

Proximal Tibia Fractures

Although closed treatment and definitive external fixation remain options in the management of extra-articular proximal tibia fractures, the prevalent approach for most surgeons is via internal fixation. The choice between plating and IM nailing when either may be applicable is a matter of debate. Although IM nailing of the tibia has become the standard of care for most tibial diaphyseal fractures, treating proximal tibia fractures with IM nails has proved to be particularly difficult.[1,2] Poor results with these fractures have led to some authors to recommend against nailing in favor of plating. Some limitations may remain, but several adjunct techniques have been developed by expert surgeons to improve the results and further expand the indications for nailing to include these proximal fractures.[1,3-5]

Figure 1



AP (**A**) and lateral (**B**) radiographs demonstrating bicortical reduction plating. Careful plate application allows for secure fixation of an unstable proximal tibia fracture before nailing.

Kuntscher[6] described two positions for nailing tibial fractures: with the knee flexed to 90° and with the knee only slightly flexed. Currently, the most common technique and position used are infrapatellar nailing with the knee in a fully flexed position. This allows access to the optimal starting point for nail insertion.[7] With proximal fractures, increased tension on the knee extensor mechanism in the flexed position exaggerates the deforming forces. The anterior pull on the tibial tubercle results in a flexion and anterior translation deformity. A valgus deformity is commonly seen, as well, likely the result of imbalance associated with the hamstring and anterior compartment musculature.[8]

In 1995, two simultaneously published series reported high incidences of proximal tibia malreduction with nailing. Freedman and Johnson[1] noted a malreduction rate of 58%, and Lang et al[2] described a malreduction rate of 84%. Contrarily, Cole et al[9] noted acceptable alignment in 92.3% of proximal tibia fractures treated with nail fixation. Over the next 15 years, refined techniques and improved implants have resulted in the authors of multiple clinical series[3,10-13] reporting outcomes more consistent with those of Cole et al.[9]

Reduction Techniques and Tips

Supplemental Plates

The most invasive approach involves reducing the fracture in an extended position and applying a unicortical plate that does not impede the passage of an IM nail.[5,10,11] This allows for subsequent flexed-position nailing, and the plate can then be removed or left in place. This often requires open exposure of the fracture and release of the fracture hematoma as well as periosteum stripping, which may compromise the healing potential, especially in the setting of an IM implant. In open fractures, additional exposure may not be necessary. Percutaneous plate application is possible in some settings. There is a theoretic increased risk of infection and wound healing complications. Careful soft-tissue technique will mitigate some of these risks. Bicortical plates are occasionally applicable in settings in which the screws can be aimed around the nail (Figure 1).

Reduction Forceps

Less invasive options may also allow for the provisional reduction of the fracture and temporarily resist deforming forces during the insertion of the implant. Alignment can be achieved and secured using percutaneously applied reduction forceps.[11,14] This technique requires careful attention to soft-tissue compromise and the location of neurovascular structures. Oblique and spiral fractures are typically more amenable to this technique. The clamp application is generally determined with multiplanar fluoroscopic assistance. Proximally applied clamps may not be strong enough to resist the forces associated with nail insertion in the more proximal tibial fractures.

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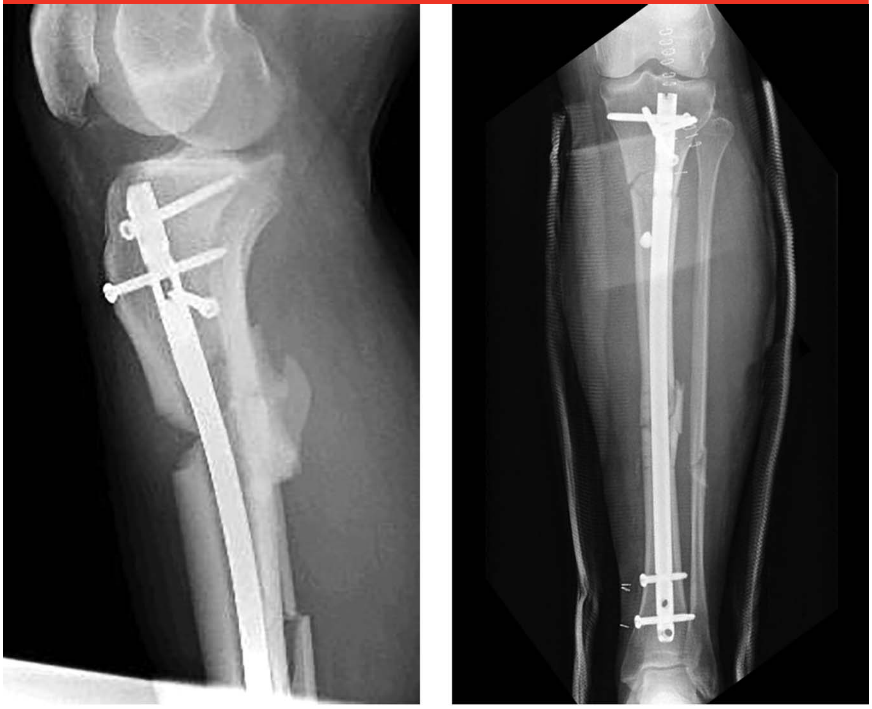
Figure 2



A

B

A, Lateral radiograph demonstrating blocking screw in the sagittal plane in the treatment of a proximal tibial fracture. The medial screw prevents a more unusual varus deformity. The screw narrows the effective endosteal canal diameter. **B,** AP radiograph demonstrating blocking screw in coronal plane. The posterior screw maintains sagittal alignment and keeps the nail positioned anteriorly.

Figure 3

Intraoperative photograph demonstrating use of the femoral distractor in the treatment of a proximal tibial fracture. The pins are applied medially and posteriorly to the nail. This allows unimpeded passage of the nail while a varus moment corrected the tendency to valgus angulation. Flexion deformity correction was facilitated with operating room towels stacked distal posterior. The fracture reduction is completed without the need for manual assistance.

Blocking Screws

Blocking screws are another option to help prevent displacement and to direct the nail. Krettek et al[4] showed improved mechanical stability with this technique, and several clinical series demonstrated satisfactory results with the use of blocking screws.[3,9,13,15] Screws placed adjacent to the nail from anterior to posterior help prevent coronal plane deformity (Figure 2, A). Screws placed posterior to the nail in the coronal plane help prevent procurvatum or flexion (Figure 2, B). These screws must be accurately placed to be effective and must have sufficiently secure placement to resist the forces of nail insertion. Osteopenic bone or proximal fracture extension may diminish the efficacy of this technique.

Schanz Pins/Femoral Distractor

Percutaneous use of Schanz pins as joysticks may aid in the reduction of the fracture. Use of a femoral distractor is an extension of this concept. The distractor is commonly applied medially with posterior positioning of the Schanz pins (Figure 3). The proximal pin can serve as a temporary blocking screw if desired.[11] Because multiplanar pins cannot be used with the distractor, adjunct techniques may be necessary to achieve an anatomic reduction. An external fixator device with multiple pins placed proximal to and distal to the fracture may allow for better fragment control.

Nail Starting Point and Design

In addition to understanding that the fracture must be reduced before the introduction of the nail, the surgeon must appreciate the additional challenges presented by the nailing technique. If the surgeon does not accurately introduce the nail in the proximal fragment, directly in line with the diaphyseal canal, the alignment will be impossible to maintain. Furthermore, achieving stable fixation is not a trivial challenge because the proximal segment is short and locking screws are secured in metaphyseal cancellous bone.

Surgical reduction techniques described to date include the use of a more proximal and lateral starting point.[2] This allows for more anterior and lateral positioning of the nail, and when the implant is directed properly, may help prevent iatrogenic fracture displacement. A more medial starting point will exaggerate valgus deformity, and a more distal starting point will cause procurvatum.

Figure 4

Intraoperative photograph demonstrating incision placement for a nail proximal to the patella.

Early nail design did not address the problems associated with nailing proximal fractures and may have exacerbated them. A distal Herzog bend had a tendency to create a wedge effect, pushing the distal fragment posteriorly.[16] Proximal locking holes were relatively limited and oriented in a single plane, with no fixed-angle options. Nail manufacturers in more recent designs have addressed many of these design parameters. Guided blocking screw insertion has been introduced to an instrument platform. Furthermore, instrumentation has been developed to facilitate the insertion of IM nails in the extended (or semiextended) position.

Suprapatellar Nailing

Recognizing the flexed position of the knee as contributory to the deformity, Tornetta and Collins[12] revisited nailing in the semiextended position in 1996. In their clinical study, a consecutive group of fractures was treated with the standard tibial nailing technique; the technique was changed to nailing in the semiextended position, with an extended parapatellar approach. The postoperative alignment seen in this nonmatched, consecutive series showed considerable improvement. Although limited clinical series exist and not every author has had equal success with this technique,[13] surgeons have begun to see advantages in this approach. Combining nailing in the semiextended position with the various techniques already mentioned can be very effective.

Other advantages to semiextended nailing have been reported. Although no published study to date has examined the differences in surgeon radiation exposure between suprapatellar and traditional tibial nailing, proponents of the suprapatellar technique report advantages. In addition, true in-plane, orthogonal fluoroscopy is less challenging, especially in establishing a proper starting point. Also, with the leg fully supported in the semiextended position, the effort in obtaining a reduction and maintaining alignment throughout the procedure may be facilitated (Figure 4). It has been suggested that this may diminish the need for an assistant surgeon. These hypotheses warrant further investigation. The availability of alternative surgical sites is a reported advantage. This can be particularly useful in the setting of traumatized infrapatellar skin.[17] Furthermore, applicability of the technique to other challenging fracture patterns, such as segmental and distal metaphyseal fractures, is noted.

Knee pain after tibial nailing remains an unresolved issue. The incidence of postoperative anterior knee pain following traditional nailing has been reported to be as high as 86%.[18-20] Various potential sources of anterior knee pain are hypothesized with little clarity, and multiple factors are probably contributory. Morandi et al[21] indicate that theoretic advantages may exist that mitigate knee pain with the suprapatellar technique, including limiting superficial surgical dissection in the region of the proximal tibia and the avoidance of the infrapatellar branch of the saphenous nerve.

Three outcomes studies have been published to date. Jones et al[22] published a retrospective, therapeutic level III evidence study that looked at 74 consecutive traumatic (n = 64) or reconstructive (n = 10) nailing cases. Suprapatellar nailing was performed in 36 cases and infrapatellar nailing in 38. Follow-up was available in 59 of 74 patients. There was improved coronal alignment and improved entry point location with suprapatellar nailing, although there was no difference in knee pain between the two groups. Restoration of accurate length was more reliable with suprapatellar nailing.[22]

In a therapeutic level III retrospective cohort study, Ryan et al[23] looked at 84 patients with proximal or distal metaphyseal tibia fractures and 101 patients with diaphyseal fractures, all treated with tibial nailing. The metaphyseal fractures were nailed in the semiextended position, whereas the diaphyseal fractures were nailed with standard infrapatellar technique. Average follow-up was 2.3 years. There was no statistical difference in knee pain between the semiextended and flexed-knee infrapatellar groups.[23]

Finally, in a prospective, nonrandomized, nonconsecutive (level IV) study by Sanders et al,[24] outcomes were tracked at a minimum of 1 year in 37 of 56 tibia fractures treated with suprapatellar nailing. The authors reported minimal knee pain associated with the suprapatellar surgical procedure. Based on these outcomes studies,[22-24] it appears that the suprapatellar nailing technique allows for an alternative approach that does not result in increased knee pain and may yield advantages.

Contrarily, the approach and possible transarticular introduction of the tibial nail presents theoretic disadvantages or risks specific to the nature of the procedure. These concerns include risk of injury to patellar or femoral trochlear cartilage, risk of iatrogenic injury to other intra-articular structures, risk of joint sepsis or of intra-articular retained reaming debris, and the challenge of nail removal. Clinical reports are sparse.

The risk of iatrogenic damage to the patellar and femoral articular surfaces has been the primary concern for many surgeons in performing this technique, particularly with a transarticular approach. This has prompted studies of articular damage, both in the laboratory and clinical settings. Gelbke et al[25] showed in a cadaver biomechanical study that the forces engendered in transarticular suprapatellar nailing exceeded the forces in the patellofemoral joint with infrapatellar tibial nailing. The forces measured remained below the reported threshold for chondrocyte death and below the contact pressures measured with simple knee flexion. Post-procedural macroscopic[26] and arthroscopic[27] assessment of the articular surfaces for chondral damage has shown no evidence of injury in cadavers. Initial clinical evidence of trochlear or patellar cartilage injury in clinical series had been limited to two cases in the first series.[12] More recently, in the series by Sanders et al,[24] 15 of their 56 patients underwent arthroscopy before and subsequent to the nailing procedure; Outerbridge grade II chondromalacia changes were identified in two patients (13.3%). Thirty-three of 37 knees were assessed with 1-year MRI scans. Although two patients had MRI scans showing patellofemoral changes, neither patient with an abnormal MRI study had abnormal arthroscopic findings, and neither had clinical adverse results. The clinical incidence may be technique dependent because patella-subluxating techniques may result in lesser forces through the patellofemoral joint.

The risk of damage to other intra-articular structures has been studied with regard to both the infrapatellar technique[28,29] and the suprapatellar technique,[26,30] and in comparison studies.[27,31] These studies revealed the risk of injury to other intra-articular structures, as well, such as the intermeniscal ligament, the menisci, the anterior cruciate ligament footprint, and medial and lateral proximal tibial articular surfaces. The comparative studies yielded unclear results regarding any advantage in this regard with respect to the surgical approach.

There are no published reports to date of joint sepsis or complications related to intra-articular reaming debris following transarticular tibial nailing.

Plating Versus Nailing

Clinical series comparing the outcomes of proximal tibia nail versus plate fixation are limited. Lindvall et al[32] performed a retrospective comparative study with 22 patients in the IM nail group and 34 patients in the percutaneous locked plate group. Nailing was performed in the flexed position. The authors were unable to show any statistical difference between groups with respect to union rates, malunion or malreduction, infection, or need for implant removal. However, small numbers may have contributed to the lack of statistical significance, and hardware removal was necessary three times more frequently for plates (15%) than for nails (5%) in this series. There is limited clinical evidence to show a clear advantage with plating or nailing of proximal tibia fractures; both options remain valid. Surgeon familiarity with the technical aspects of each approach, implant limitations, and soft-tissue factors may be contributory in the decision-making process.

Distal Tibia Fractures

Distal tibia fractures are managed with either nailing or plating in the metaphyseal region, with or without extension into the articular surface.[33] Treatment of fractures occurring in this region is fraught with pitfalls, and complications may arise from using any one technique.

The difficulty in treating distal tibia fractures is related to the ability to attain and hold the reduction of the fracture while maintaining adequate fixation until healing has occurred. Other factors that may play a role are the discrepancy between the diaphyseal and metaphyseal bone diameters and the short-segment distal fragment, which makes achieving and holding the reduction difficult. Various techniques are used to achieve the reduction, as described below.

A few randomized studies compare nailing and plating and show equivocal results, with some differences noted in the functional outcome and infection rates.[34-38] In their study on the radiographic comparison of tibias treated by one of the two techniques, Vallier et al[37] showed that delayed union, malunion, and secondary procedures were more frequent after nailing, with no difference in functional outcomes. It was noted, additionally, that there was a higher incidence of ankle and knee pain with nailing and that both groups did worse than did the normal population. Mauffrey et al,[38] in a later trial, conversely showed that there were more secondary procedures in the plating group, although they

Figure 5

Postoperative AP radiograph of a distal tibia fracture treated with an intramedullary nail. The fibula was plated to aid in the reduction of the fracture.

Figure 6

Postoperative AP radiograph of a distal tibia fracture treated with a medial locking plate. The fibula has been fixed using an intramedullary nail.

had only 24 patients in their study. Interestingly, Im and Tae,[34] in a larger trial, found that shorter surgical times with improved function and decreased complications were seen in the nailing group.

Some of the disadvantages of open plating (eg, periosteal stripping, soft-tissue breakdown) have been mitigated with the use of minimally invasive plating, which has expanded the use of plates for distal tibia metaphyseal fractures. The advantages of nailing, which include minimal soft-tissue dissection or exposure at the fracture site, may now be diminished with these minimally invasive techniques. Excellent healing rates and union rates have been reported using this technique.[39,40]

The role of fibula plating in achieving and maintaining fracture reduction of the tibia while nailing or plating is also controversial.[41,42] Egol et al[42] showed that fibula plating helped in complex/comminuted fractures intraoperatively to stabilize and hold the reduction of the tibia by creating a lateral strut. The study by Vallier et al[37] comparing plating versus nailing, with or without fibula fixation, demonstrated a higher rate of nonunion in patients who underwent fibula plating, although the plating was helpful in reduction of the tibia fracture (Figures 5 and 6).

Biomechanical studies have demonstrated that reamed nails may be stronger than unreamed locked nails or locked plating in fixation of these injuries.[43] These results potentially support the use of nails for weight bearing, although this may ultimately be decided by fracture comminution, proximity to the articular surface, and extension into the joint. A recent study showed no difference in fracture healing or complications with early weight bearing after tibial nailing.[44] In nailing, there is no change in the starting entry point at the proximal end; however, certain maneuvers, as described here, are useful for distal fractures. Initial external fixation may be useful for soft-tissue management or for intraoperative manipulation and as an aid to reduction. Nailing can be performed acutely; however, if the plan is for plating, it is advisable to wait for swelling to diminish.

The starting point of the nail is similar to that for any other tibial nail; however, the ending point of the guidewire must be center-center on both AP and lateral fluoroscopy views to prevent deformity. Unlike diaphyseal fractures, nail insertion in distal metaphyseal fractures does not result in fracture reduction. Eccentric reaming or failure to control the distal fragment can lead to notable malalignment and deformity.

If intra-articular extension is noted, it should be reduced and stabilized first, before reaming; the goal is to prevent displacement of the articular surface while attempting nailing. Kirschner wires for use with cannulated screws are inserted to capture the articular fragments and are placed such that they do not block the path of the nail (usually distal). If this is not possible, then plating should be considered (Figure 7).

Use of blocking screws may be required to guide passage of the nail into the desired location by blocking passage of the nail into undesirable location. Blocking screws are typically inserted on either side of the nail to guide its passage to the center-center position.

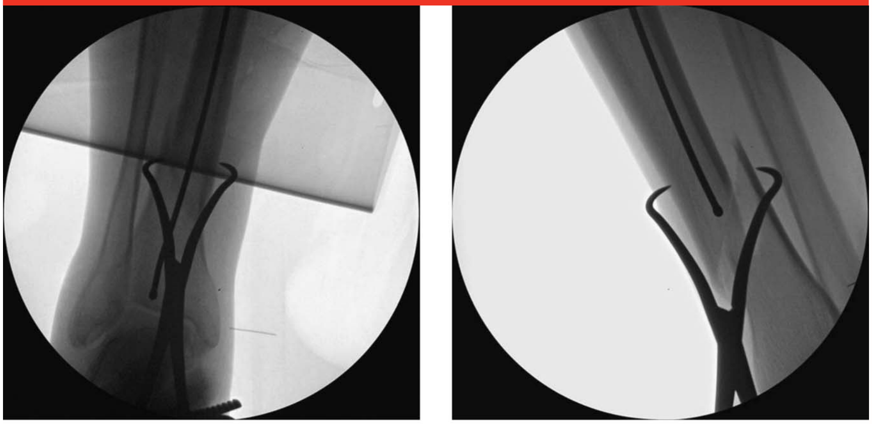
Bone reduction clamps may be used for percutaneous application to reduce and hold the fracture; small incisions for the tines of the clamps are preferable to poking through the skin; this allows closure at the end and will prevent drainage of hematoma through these so-called poke holes (Figure 8).

Performing the distal locking first is recommended to hold reduction; care should be taken to reassess the fracture because it is possible to displace

Figure 7

Postoperative AP radiograph demonstrating the use of screws for articular reduction in the distal tibia, which is done before insertion of nail to avoid disruption of the articular surface.

Figure 8



A

B

Intraoperative AP (**A**) and lateral (**B**) fluoroscopic view demonstrating an intraoperative bone reduction clamp used to allow for fracture reduction in the distal tibia. Use of the clamp is important to allow passage of the guidewire and nail into the desired location in the distal segment.

the fracture (usually into valgus) as a result of pressure from the drilling and screw insertion unless the fracture is held with a bone-reduction clamp or plate.

Use of three (or the maximum number possible) distal locking screws is helpful in increasing the fixation strength and holding the reduction.

The following surgical tips are useful in managing these difficult fractures. Either one or multiple techniques may be applied to achieve and maintain reduction of the fracture and can be used for either nailing or plating.

Inserting a Schanz pin parallel to the joint in the distal tibia posterior to the midline will allow both traction and fracture reduction in conjunction with an external distractor and a proximal tibial pin.

Use of percutaneous, pointing bone-reduction clamps will allow reduction, especially in spiral/oblique fractures.

Blocking screws can be inserted percutaneously and act to decrease the width of the metaphyseal medullary canal, facilitate reduction, prevent nail translation, and increase the strength of the fixation construct.[4]

Applying additional small plates for provisional reduction is helpful for both plating and nailing. This can easily be done when nailing open fractures, where the open wound allows placement of a small fragment plate for reduction.[5] Care must be taken to insert unicortical screws to allow for passage of reamers and the nail.

Application of a uniplanar external fixator or femoral distractor for alignment and length, especially in comminuted or segmental fractures, is useful for both nailing and plating.

Multiple distal fixation points in nailing (three locking screws) or plating (multiple screws) is recommended to hold the reduction to healing.

Use of an incisional vacuum-assisted closure dressing may be helpful in decreasing edema and wound complications, especially after plating.[45]

Summary

Fractures of the metaphyseal region of the tibia can be treated satisfactorily at the distal end using a plate or a nail. At the proximal end, the use of a suprapatellar technique for nailing offers a viable and safe alternative to other techniques for metaphyseal fractures. Reduction and stabilization of these injuries demands an exacting technique and attention to detail to avoid malunion, nonunion, and wound complications. However, the outcomes can be improved with use of the techniques described, appropriate soft-tissue management, and management of patient expectations.

References

Evidence-based Medicine: Levels of evidence are described in the table of contents. In this article, references 3, 13, 15, 19, 34-36, 38, and 45 are level I studies. References 1, 2, 5, 11, 12, 18, 20, 32, 37, 40, 41, and 43 are level II studies. References 22 and 23 are level III studies. References 24 and 39 are level IV studies.

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