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## Avoiding Complications in the Care of Fractures of the Tibia

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### Abstract

*Tibial fractures are the most common long-bone fractures. Orthopaedic surgeons, regardless of their subspecialty, often must treat these injuries, which range from low-energy, minimally displaced fractures to limb-threatening injuries with neurologic and vascular damage and significant damage to the soft-tissue envelope. Tibial shaft fractures are often prone to complications, such as apex-anterior and valgus malalignments after nailing of the fractures in the proximal one third of the tibia, infection after open fractures, and aseptic nonunions. Understanding the common complications will aid in preventing them and will allow recognition and provide treatment strategies when such problems occur.*

**Instr Course Lect 2009;58:27-36.**

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Tibial fractures are the most common long-bone fractures, with the National Center for Health Statistics reporting an annual incidence of 492,000 fractures of the tibia and fibula per year in the United States.<sup>1</sup> Fractures of the tibial shaft range from low-energy, minimally displaced fractures to limb-threatening injuries with associated nerve and

arterial damage and major damage to the soft-tissue envelope. Even the lower-energy tibial shaft fractures are not as benign as they seem. Common problems include deformity after intramedullary nail fixation of the fractures in the proximal one third of the tibia, infections after open fractures, and aseptic nonunions. This chapter reviews these

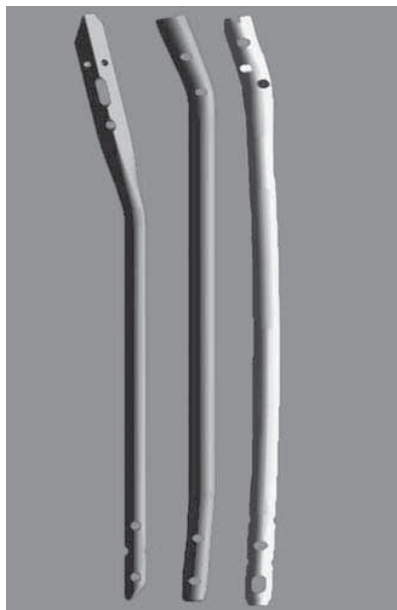
three common complications, with an emphasis on prevention, recognition, and treatment.

### Intramedullary Fixation of Proximal Tibial Fractures

Fractures in the proximal one third of the tibia are prone to malalignment, with the prevalence of that complication reported to be as high as 84%.<sup>2-4</sup> The most common type of malalignment is apex-anterior and valgus angulation.<sup>2-6</sup> Occasionally, a proximal tibial fracture is part of a segmental tibial fracture, which is not only a challenge to treat with nailing but also may have delayed healing. The anatomy of the proximal part of the tibia must be understood because it presents potential problems with fixation. First, the tibial metaphysis is wide, and insertion of the nail alone cannot effect reduction; thus, the metaphyseal portion of the tibia must be aligned with the shaft of the tibia by another method.<sup>7</sup> The forces of the patellar tendon contribute to the flexion deformity.<sup>3,4,6,7</sup> As the knee is flexed

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**Figure 1** The proximal curvature of tibial nails can vary substantially.

for standard intramedullary nailing, a proximal tibial fracture becomes angulated as a result of the cephalad pull of the patellar tendon.<sup>6</sup> Methods to minimize this are described in this chapter. Because the medial cortex of the proximal part of the tibia slopes from proximal to distal, if the starting point for the intramedullary nail is too medial, the nail insertion will produce a coronal plane deformity.<sup>4-6,8</sup> When there is comminution of the posterior cortex, the nail may not be contained within the proximal fragment, leading to apex-anterior angulation.<sup>4</sup> Finally, insertion of a nail can be difficult because it requires hyperflexion of the knee, which can be problematic with a fracture in the proximal tibial metaphysis. As noted, the intramedullary nail cannot be used to reduce a fracture in the proximal tibial metaphysis. The fracture must be reduced by manipulation, and the reduction must then be maintained



**Figure 2** Lateral fluoroscopic view of the optimal starting point for proximal tibial nailing. Note that the guidewire is parallel to the anterior cortex.



**Figure 3** AP fluoroscopic view of the optimal starting point for proximal tibial nailing.

while the tibia is reamed and until interlocking is completed. With proper technique, intramedullary nailing of proximal tibial fractures can lead to good results.<sup>4,5,7</sup>

The geometry of tibial nails must be considered when planning their use. Tibial nails may have a proximal posterior bend of up to 14° (Figure 1). The position of the bend in the nail also varies. Henley and associates<sup>2</sup> showed that the more distal the bend of the nail, the greater the chance for proximal fracture malalignment. A tibial nail that is to be used for fixation of a fracture in the proximal metaphysis should have as proximal a bend as possible, and attention should be paid to the degree of curvature of the bend. It is also important to consider what locking options are available. Biomechanical studies have demonstrated that the construct stability of an oblique screw locking configuration is greater than that of a transverse locking configuration.<sup>9-11</sup>

There are several techniques for preventing malalignment when a nail is used to treat a proximal tibial fracture. The starting point for the nail is critical. To minimize prob-

lems with apex-anterior and valgus angulations, the starting point should be as proximal as possible, and the guidewire should be advanced parallel to the anterior cortex (Figure 2). If the leg is externally rotated, the starting point may be more medial than desired despite fluoroscopy.<sup>12</sup> The optimal starting point is the medial aspect of the lateral tibial eminence because this will place the nail in line with the medullary canal (Figure 3). With most tibial shaft fractures, the starting point may be found by using a threaded guide pin or an awl, but for these difficult proximal fractures, it is better to use a threaded guide pin to provide a more precise starting point. In addition, in a report describing the use of a semiextended knee position, Tornetta and Collins<sup>6</sup> reported two fractures that required augmentation because it was believed that the awl created too large a defect in the tibia.

Under fluoroscopy, a femoral distractor can be used to facilitate reduction and stabilization of a proximal tibial fracture. The Schanz pins should be placed proximally and distally in the medial aspect of the tibia, parallel to the articular surface.

Also, the proximal pins can be placed in the posterior aspect of the proximal part of the tibia to mimic a blocking screw.<sup>7</sup> External fixation can be used, in the same manner, as an alternative to the femoral distracter.

Nork and associates<sup>7</sup> reviewed 35 patients with a total of 37 fractures involving the proximal quarter of the tibia treated with intramedullary nailing. They checked the behavior of the proximal fragment before nail insertion and discovered that, if the reduction was lost with knee flexion, it was important to use certain techniques to keep the fracture reduced.<sup>7</sup> They suggested using a starting point for the nail that is parallel to the anterior cortex of the tibia and in line with the lateral intercondylar eminence, along with a medial femoral distractor and/or augmentation of the fixation with a short plate. If a short plate is used to augment the fixation, it can be left in place or removed at the discretion of the surgeon.

Instead of positioning the knee in flexion, Tornetta and Collins<sup>6</sup> used a semiextended knee position for nail insertion. They performed a medial parapatellar arthrotomy and subluxated the patella laterally. This minimized apex-anterior angulation and placed less tension on the soft tissues. With lateral subluxation of the patella, the trochlear groove could be used as a conduit for nail placement. In this technique, the knee was not flexed more than 10° to 15°. The disadvantage of the method is that it requires a formal arthrotomy.

Another option for preventing malalignment is to use a unicortical plate. Archdeacon and Wyrick<sup>13</sup> described reduction plating for provisional fixation of multiple long-bone fractures. Benirschke and associates<sup>14</sup> advocated this tech-

nique to prevent the common deformities that occur with nail fixation of proximal tibial fractures. It is necessary to plan ahead so that the plate is placed in the optimal position to assist with the reduction and not interfere with guidewire placement and reaming. A one-third tubular conventional or locking plate or a low-contact dynamic compression plate may be used with multiple unicortical screws 10 to 14 mm in length and with at least two screws in both the proximal and the distal segments. The plate can be placed subcutaneously. A locking plate and screws adds more cost to the procedure, but the unicortical fixation provided by locking screws is stronger than that offered by standard unicortical screws. The reduction plate maintains the alignment of the fracture during the tibial nailing. If the surgeon chooses to remove the plate, this should not be done until after the proximal and distal locking screws of the nail have been placed.

The use of blocking screws with intramedullary nail fixation has been described as having good results in the treatment of fractures of the proximal third of the tibia.<sup>4,9</sup> In addition to minimizing malalignment associated with the nailing of proximal tibial shaft fractures, blocking screws increase the stability of the construct by 25%, as demonstrated by Krettek and associates.<sup>9</sup> This is an important consideration when increased biomechanical strength is desired. Blocking screws are placed where the surgeon does not want the nail to go. The screw is placed lateral to the central axis to control valgus angulation. The nail then passes medial to the screw, and, as it passes across the fracture site, valgus angulation is avoided. A blocking screw is placed posterior to the central axis, with the nail passing anterior-



**Figure 4** A blocking screw has been placed to minimize apex-anterior angulation.

or to it, to prevent apex-anterior angulation (Figure 4). Ricci and associates<sup>4</sup> used this technique to treat 10 acute fractures and two malaligned nonunions. Although the sample size was small, all patients had less than 5° of deformity postoperatively.

There are alternatives for the treatment of these fractures. Plate fixation is an attractive option for surgeons who are uncomfortable with intramedullary nailing. However, the patient must have a good soft-tissue envelope; otherwise, the risk of a complication is excessive.<sup>15</sup> External fixation is another alternative with which to treat proximal tibial shaft fractures.<sup>16</sup> However, this procedure may require augmentation with bone graft to promote healing and should be reserved for fractures associated with so much soft-tissue injury that internal fixation is contraindicated.

The key to successful nailing of a proximal tibial fracture is to understand the fracture and its deforming forces and to maintain the reduction during guidewire placement, subsequent reaming, nail placement, and locking of the nail. Careful attention to detail and respect for the unique

difficulties presented by this fracture will result in acceptable reduction, stable fixation, and a high rate of healing.

### Infections

Infection is a dreaded complication after any fracture but especially after tibial fractures because the treatment of an infection in the tibia is a particular challenge. The infection rate following closed tibial shaft fractures is approximately 1%.<sup>8</sup> Open fractures are associated with higher infection rates: 5% for Gustilo and Anderson type I, 10% for type II, and more than 15% for type III.<sup>8</sup> The soft-tissue injury is a key factor affecting the risk of infection, and the appropriate treatment of that injury has a strong influence on the outcome.

The key to preventing infection following an open tibial fracture begins with the initial débridement. Meticulous techniques should be used to débride the fracture from the outside skin portion through to the deep osseous portion. All nonviable tissue, both osseous and soft tissue, should be removed. If there is any doubt regarding the viability of the tissue or bone, it should be taken out. The exception is articular cartilage and the subchondral bone, which should be preserved if at all possible. The extent of the soft-tissue injury does not completely manifest itself initially, and there may be necrotic tissue that appears viable at the initial débridement; therefore, multiple débridements should be done.

When an external fixator is initially used, it is best to convert it to a definitive internal fixation device within the first 7 days, as increased infection rates have been reported in association with delayed conversion.<sup>17,18</sup>

Early soft-tissue coverage of type IIIA fractures helps to prevent

infection, and the timing of the coverage is crucial for successful treatment. Fischer and associates<sup>19</sup> evaluated 43 patients with a type IIIB tibial fracture to determine the effect of treatment of the soft-tissue injury on the rate of complications. Infection developed in 2 of the 11 patients treated with early muscle-flap coverage, in 10 of the 19 treated with open wound care, and in 9 of the 13 patients treated with delayed flap coverage. Fischer and associates<sup>19</sup> concluded that early flap coverage is important to reduce the infection rate. This finding is consistent with a previous report that the highest rate of complications occurs when flap coverage is done more than 2 weeks after the injury. It is believed that the wound is only contaminated with bacteria initially, but colonization occurs during the first 2 weeks and leads to the increased risk of infection associated with delayed closure.<sup>19</sup> A flap placed early provides a healthy environment, promotes healing, and increases blood supply, leading to re-epithelialization. All of those factors decrease wound colonization and the risk of contamination of deeper tissues.

Infections may develop in the acute period, which is defined as less than 4 weeks after the injury.<sup>8</sup> Infections also can occur several months to years after the injury. It is not necessarily easy to recognize these late infections, and one must be aware of this possibility. A type or mechanism of initial injury that predisposes a patient to infection should make one more vigilant about detecting this complication. Was there a major crush component? Was there soft-tissue devitalization? Was an open fracture sustained in a contaminated environment (involving, for example, soil, chemicals, or murky lake

water)? These factors may contribute to indolent or delayed infection.

Comorbidities contribute to the risk of an infection. The nutritional status is important, and often patients who have sustained trauma are protein depleted. A patient may be immunocompromised, have diabetes, use tobacco, or abuse drugs or alcohol. When possible, these host comorbidities should be treated while the fracture is being treated. The patient's nutritional status is evaluated by measuring the blood glucose level, serum prealbumin level, total protein level, and lymphocyte count. When a patient has diabetes, the blood glucose level should be carefully controlled. Smokers are more prone to infection, and it is well known that their fracture-healing time is increased by up to 40%.<sup>20-22</sup> Patients with a systemic disease such as rheumatoid arthritis may be taking medications that interfere with healing and may be more prone to infection.<sup>23</sup> Patients with vascular insufficiency may have important circulatory issues. A heightened index of suspicion for infection should be maintained for patients with any of these comorbidities.

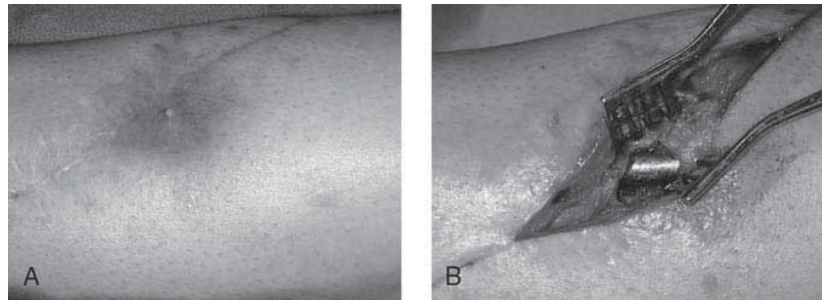
Obvious signs and symptoms of infection include increasing pain, swelling, erythema, fever, chills, and purulent drainage, but prolonged or increasing pain may be the only clue that the patient has an infection (Figure 5). The periosteal reaction usually seen with hematogenous osteomyelitis may not be present, and bone scans can be inaccurate; false-negative scans are not uncommon. If infection is suspected, determination of a complete blood cell count with differential, the erythrocyte sedimentation rate, and the C-reactive protein level may help in making the diagnosis. The erythro-

cyte sedimentation rate may be elevated as a result of the injury and surgery, but it should decrease with time. C-reactive protein is an acute-phase reactant, and it should return to normal after the injury more quickly than the erythrocyte sedimentation rate. If it remains elevated, infection should be considered. Furthermore, the C-reactive protein level provides a means of determining the effectiveness of treatment of an infected wound.

Once an infection has been identified, treatment should be definitive. The most important part of management is débridement to remove all nonviable bone and soft tissue.<sup>24</sup> Aggressive débridement should be repeated until the wound is clean and has an acceptable soft-tissue envelope. Soft-tissue and bone specimens should be obtained for culture, and the appropriate systemic antibiotic therapy should be instituted.<sup>24,25</sup>

If the débrided wound cannot be closed, a vacuum-assisted closure device may be used until there is adequate granulation tissue to support appropriate coverage. The ultimate goal is soft-tissue coverage but not until the tissue bed is acceptable.

Direct application of antibiotics seems to be beneficial, and a variety of options are available to deliver a high concentration of local antibiotics.<sup>26</sup> Polymethylmethacrylate beads mixed with antibiotics can be used. These beads provide an advantage because of their surface area and the local delivery of the antibiotics. The disadvantages of using polymethylmethacrylate beads are that the maximal antibiotic concentration is delivered within the first 2 weeks and a second surgical procedure is required to remove the beads. Calcium sulfate pellets are a commercially available alternative. These can



**Figure 5** Photographs of a patient with purulent wound drainage. **A**, Before débridement. **B**, After débridement. Note the exposed intramedullary nail.

be mixed with antibiotics and do not require removal. Unfortunately, the pellets can stimulate local inflammation with drainage that may be mistaken for an infection. Systemic antibiotic administration is recommended, and 6 weeks of culture-specific intravenous antibiotics is usually sufficient. Monitoring the erythrocyte sedimentation rate and C-reactive protein level assists in the determination of when the infection is controlled. It is also important to routinely monitor renal and hepatic function when drugs that are cleared through those major organ systems are used. A controversial topic is when the implant should be removed. When the infection develops early, before any healing occurs, the patient should be treated with aggressive débridement, wound closure, and suppressive antibiotics without removal of the hardware. When this is done, the healing rate can approach 90%.<sup>8</sup> When the infection is diagnosed more than 4 weeks after the injury, the hardware may need to be removed to eradicate the infection. If the fixation is unstable, the implant should be removed, the infected area should be débrided, and appropriate antibiotics should be administered to treat the infection. An external fixation device may be needed to

control the unstable fracture. If necessary, internal fixation may be performed later, but only after wound specimens are culture negative and the patient is receiving an appropriate systemic antibiotic. If the fixation is stable and the soft tissues are healthy but the fracture is not healed, it may be possible to retain the hardware, perform a thorough débridement, and use local and systemic antibiotics. If the infection returns or if signs of deep infection persist, the implant should be removed.

### Aseptic Nonunions

Nonunions are frustrating for both the patient and the surgeon. Aseptic nonunion occurs after approximately 3% of closed tibial shaft fractures.<sup>8</sup> The nonunion rate after open fractures is 15% or greater depending on the degree of the soft-tissue injury. A patient with a nonunion is subjected to multiple surgical procedures and additional hospitalizations and has an increased duration of disability. An amputation may eventually be needed. An awareness of which fractures have an increased potential for healing problems is valuable because this allows earlier intervention, which reduces the time to union. The orthopaedic community has not agreed on the length of time re-

quired for a tibial fracture to heal, but the US Food and Drug Administration (FDA) has defined nonunion as a fracture that occurred a minimum of 9 months previously and has no radiographic signs of progression toward healing for 3 consecutive months.<sup>27,28</sup>

Nonunions are classified, on the basis of radiographic appearance, as either hypertrophic or atrophic. Hypertrophic nonunions have abundant callus surrounding the bone but a persistent radiolucent line at the fracture site. They are considered to have an adequate biologic environment but lack sufficient mechanical stability. In contrast, atrophic nonunions have little or no callus on radiographs and are considered to be caused by an inadequate biologic environment.

Numerous factors contribute to an aseptic nonunion. Host factors that increase the risk of nonunion are similar to those that predispose a patient to the development of an infection. Patients with diabetes mellitus have longer fracture-healing times.<sup>29</sup> Smokers have an increased rate of nonunion and more soft-tissue healing problems than do nonsmokers.<sup>20-22</sup> Several medications may interfere with fracture healing. These include nonsteroidal anti-inflammatory drugs and bisphosphonates when taken in the early postoperative period.<sup>23,30</sup>

Nutrition is a factor that also needs to be considered when a patient has a nonhealing fracture. Even an overweight patient may be malnourished. Inadequate nutritional status is defined by an albumin level of less than 34 g/L and a lymphocyte count of less than  $1,500/\text{mm}^3$  ( $< 1.5 \times 10^9/\text{L}$ ).<sup>31,32</sup>

The fracture pattern itself is an important factor. A transverse fracture may not be as simple as it

seems. Bhandari and associates<sup>33</sup> reported that a transverse fracture pattern was associated with an increased need for a revision to promote healing. Open fractures are more prone to nonunion than are closed fractures, with the higher nonunion rate probably caused by periosteal stripping and disruption of the soft-tissue envelope.<sup>34</sup> The condition of the soft tissues is the most important factor contributing to nonunions, and a closed injury may also be associated with extensive soft-tissue damage and not heal.<sup>35,36</sup> To assess the extent of the injury, the soft-tissue envelope should be palpated, and it should be noted whether degloving or other soft-tissue disruption has occurred.

The initial management of the fracture can influence healing. Concerns that reaming of the sites of open fractures would increase nonunion rates have been alleviated, and multiple studies have since demonstrated that reaming is actually beneficial when done judiciously and indeed may lead to higher union rates.<sup>26,37-43</sup> With intramedullary reaming, a large nail can be used and stability can be achieved. Static interlocking of tibial nails proximally and distally is recommended.<sup>44,45</sup> Before locking, one should ensure that there is bone-on-bone contact because, without it, a revision may be necessary to achieve osseous union.<sup>33</sup>

Once a nonunion is diagnosed, there are several surgical and nonsurgical treatment options. One nonsurgical option is weight bearing in a cast.<sup>46,47</sup> With this method, there is still some protection of the fracture site and the load-bearing may stimulate healing. Low-intensity pulsed ultrasound is another nonsurgical option, although its role in the treatment of nonunion

is controversial.<sup>31</sup> Diagnostic ultrasound can help determine which patients are candidates for surgical intervention, and it has been used to document whether there is callus formation in the early healing period following tibial fractures that are at a high risk for nonunion.<sup>48</sup> Electrical stimulation is another nonsurgical treatment option. Many companies sell electrical stimulators; currently, six external bone-growth stimulators are being sold, and all are FDA approved for the treatment of nonunions. Bassett<sup>49</sup> described a noninvasive system using pulsed electromagnetic fields. This is effective if the nonunion gap is smaller than 1 cm, with union rates ranging from 82% to 87%.<sup>49</sup> The value of electrical stimulation in the management of a patient with a nonunion remains controversial, in part because of a lack of studies with a high level of evidence.

There are a variety of surgical options for an aseptic nonunion. If the patient has an intramedullary rod with proximal and distal screws, one set of screws can be removed to allow compression across the fracture with weight bearing. This is called dynamization and can often be done as an outpatient procedure with the use of local anesthesia. However, the value of this procedure has not been well documented in studies with a high level of evidence. Court-Brown and associates<sup>50</sup> reported that dynamization had little effect on the speed of union. Wu and Shih<sup>51</sup> observed a 54% rate of union of long-bone fractures after dynamization. Complications that may occur with the removal of a locking screw are loss of fixation and migration of the nail; therefore, screw removal should be done cautiously, especially in the setting of a comminuted fracture or when the nail

is very close to either end of the tibia.

Removing the initially placed intramedullary nail and reaming the canal to insert a larger nail is called exchange nailing. This has been shown to be beneficial in the treatment of aseptic nonunions.<sup>28,31,45,46,52-55</sup> The objective is to ream the canal and place a nail that is at least 1 mm longer than the existing nail. We recommend that, when exchange nailing is performed for what is believed to be an aseptic nonunion, deep reaming specimens be sent for culture. These cultures may be positive despite laboratory indices that did not demonstrate infection, and then antibiotics can be given.

Templeman and associates<sup>54</sup> reported that 25 of 27 tibial fractures that had been initially treated with unreamed nailing and subsequently underwent exchange nailing between 3 and 5 months after the injury united after the exchange nailing. The two fractures that did not heal were associated with bone loss and required an open bone-grafting procedure to unite. The authors concluded that the procedure is safe for closed and minor open fractures but cautioned that it was associated with an increased infection rate when used for type IIIB fractures.

Court-Brown and associates<sup>52</sup> reviewed the results in 33 patients with an aseptic nonunion treated with exchange nailing. All closed and type I, II, and IIIA open fractures united, but the exchange nailing failed and open bone grafting was required for type IIIB fractures with bone loss. The authors reported that the most common complication was wound infection, which developed more often than it did after primary nailing.

Muller and Thomas<sup>45</sup> postulated two reasons why exchange nailing

stimulates bone union. The first is the increased stability provided for a hypertrophic nonunion. The second reason is that the reaming products promote healing because of their osteoinductive potential. Others have demonstrated that reaming of the intramedullary canal is associated with new bone production, and this accounts for the increased new bone after exchange nailing.<sup>52,54</sup> Overall, exchange nailing is an excellent method for the treatment of aseptic nonunions; however, the increased infection rate associated with type IIIB fractures is a concern.

Plate fixation is another option for the surgical treatment of an aseptic tibial nonunion following the initial treatment of a fracture with an intramedullary nail.<sup>31</sup> Compression plate fixation is best reserved for treatment in conjunction with bone grafting.<sup>56,57</sup> Plates are load-bearing devices, and therefore protected weight bearing is required until healing has occurred. In addition, the infection rate associated with plate fixation is higher than that associated with other methods. If the fracture is malaligned, a plate can be used to correct the alignment.<sup>31,46,58</sup>

Another surgical technique for aseptic nonunions is external fixation, such as the Ilizarov method. External fixation, either uniplanar or multiplanar, is especially useful for the management of nonunions associated with extensive soft-tissue damage, and deformity can be corrected with the Ilizarov technique. The success of external fixation depends on the patient's cooperation, and it is technically demanding. Pin-track complications are quite common, and additional operations may be required to promote fracture healing.

Bone grafting may be necessary in the treatment of some aseptic nonunions and should be considered pri-

marily for atrophic nonunions.<sup>56,57</sup> The nonunion must be stable; the placement of bone graft alone is insufficient treatment when the nonunion remains unstable. There are several options for bone grafting of tibial defects. We prefer a posterolateral approach, which is done with the patient in a lateral or prone position. The bone graft is harvested from the iliac crest only after the recipient site has been prepared to receive it. The possibility of infection at the nonunion site should be excluded, a thorough débridement should be done, and internal fixation should be accomplished. Once the bone graft has been harvested, it should be packed immediately into the nonunion site.

There are also several commercially available adjuncts, including two types of bone morphogenetic proteins (BMPs), to stimulate bone healing. Recombinant human bone morphogenetic protein-7 (rhBMP-7) was shown to promote union in a prospective study of 122 patients with a total of 124 tibial nonunions.<sup>59</sup> Nine months after surgery, 81% of the patients treated with rhBMP-7 and 85% of those treated with autogenous bone graft were judged to have a healed fracture on the basis of clinical findings, whereas 75% of the rhBMP-7 group and 85% of the autogenous bone graft group were judged to have healing on the basis of radiographic appearance. These results suggest that BMP is just as effective as autogenous bone graft for the treatment of tibial nonunions, and, on the basis of these results, the FDA approved the use of rhBMP-7 under a humanitarian device exemption.

RhBMP-2 was evaluated in two recent studies with level I evidence. In a prospective randomized study, 299 patients with an open tibial fracture

were treated with an intramedullary nail and rhBMP-2.<sup>59</sup> The use of rhBMP-2 decreased the risk of secondary intervention by 41% ( $P = 0.001$ ) and reduced the nonunion rate by 29% ( $P = 0.0075$ ). Overall, there was a 44% reduction in the infection rate as well. The FDA has approved rhBMP-2 for use in open tibial fractures treated with intramedullary fixation within the first 14 days after the injury. The use of rhBMP-2 in the acute stages may decrease the rates of nonunion and infection.

RhBMP-2 was evaluated in another prospective study of acute open or closed tibial fractures with associated bone loss that required a planned staged reconstruction.<sup>60</sup> The fracture defects ranged in size from 1 to 7 cm, with 50% to 100% circumferential bone loss. Of the 30 patients in the study, 15 were treated with rhBMP-2 and allografts and 15 were treated with autogenous bone grafts. Two patients in the rhBMP-2 group and four patients in the autogenous-bone-graft group required a secondary intervention. There was a comparable rate of healing in the two groups and fewer complications related to the donor site in the rhBMP-2 group. The authors concluded that allograft with rhBMP-2 was an alternative to autogenous bone graft for the treatment of tibial fractures with a bone defect.

### Summary

It can be a challenge to obtain optimal results following a tibial shaft fracture. The surgeon should evaluate the factors that are controllable and plan properly. This will improve the overall results.

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