Use of Interlocking Intramedullary Tibial Nails in Developing Countries

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Summary: Fractures of the tibia can be managed by Surgical Implant Generation Network intramedullary nail system in developing countries. The entry point is an important aspect of achieving accurate restoration of alignment. The fracture site should not be nailed in a distracted position. If distraction is observed, back-slapping the nail will improve bone apposition. If fluoroscopy is not used for the procedure, and the fracture site is noted to be distracted on postoperative x-rays, either revision surgery or early nail dynamization should be considered. Blocking (Poller) screws can be very helpful for proximal or distal tibial fracture management. Definitive wound closure of open fracture wounds should be achieved as soon as possible after the initial debridement surgery usually by 3 to 7 days. Leave grossly contaminated wounds open and covered with an antibiotic bead pouch if in doubt and perform repeat debridement 24 to 36 hours later. Segmental bone loss can be managed most commonly by autogenous iliac crest bone grafting although more sophisticated techniques such as bone transport are occasionally required.

Key Words: tibial fracture—intramedullary nail fixation—open fracture management—blocking screws—Surgical Implant Generation Network (SIGN)—technique.

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The Surgical Implant Generation Network (SIGN) solid, stainless steel nail was designed for use in the tibia and it is strong enough for slots rather than holes to accommodate the interlocking screw. Stainless steel was chosen because titanium implants may be more difficult to remove. The nail is straight but the proximal and distal ends of the nail have a 9 and 1.5 degree apex posterior bend, respectively. The nail is also used for femoral intramedullary (IM) nailing and these 2 bends create an effective radius of curvature which closely approximates that of the normal human femur. There are 4 iterations of the interlocking screw which has broken in less than 0.5% of SIGN interlocking nail surgeries.

Closed reduction is usually accomplished without image intensifier use if the fracture is less than 7 to 10 days old. The open reduction technique for proximal tibial fractures is different from that of distal tibial fractures. We initially used many blocking screws but these are used less frequently as the surgeon understands the technique of flexing the proximal fragment to at least 110 degree during reaming and nail insertion.

What is not clear at this time is whether a solid, hollow-slotted, or cannulated nail has a lower infection rate1 nor is there any conclusive evidence to suggest that titanium tibial IM nails are more biocompatible than stainless steel.2–5 The deep infection rate for closed IM SIGN nailing was noted to be 1.9% (16/850 tibial nails) in a recent series.6

Preparation of the patient, positioning, entry point selection, reduction of the fracture and locking screw fixation of a well-approximated, nondistracted fracture are important factors affecting the final clinical result.7,8 Patients with open fractures require early soft-tissue coverage and a careful follow-up plan to minimize the risk of infection and decrease the time to fracture union.

GENERAL CONSIDERATIONS

Preparation

The mechanism of injury and physical examination of the injured limb are important factors because high energy fractures will be more likely to become unstable with cast immobilization and prone to delayed union and malalignment. The decision to proceed with surgery is made by both the patient and surgeon. The patient, and especially the injured leg, must be carefully inspected before surgery for degree of swelling, palpation of the muscle compartments, presence of open wounds or abrasions, neurovascular status, and overall cleanliness. Shaving of hair is not recommended.9

In the operating room, surgical instruments should be checked before the patient enters the operating theater. The surgical site on the patient’s limb should be marked with an “X” and with the surgeon’s initials before entering the operating room. On induction of an appropriate anesthetic, the surgical team must carry out a preoperative or preparatory pause10,11 to verify the surgical procedure to be performed and the side of injury as recommended by the World Health Organization. The entire surgical team should be oriented to the nature of the procedure to be performed and the steps involved.

Positioning

After induction of anesthesia, the patient should be positioned on the operating table such that at least 110 degrees of knee flexion can be obtained (Fig. 1). Many surgeons use a flannel blanket placed under the ipsilateral buttock. This serves to place the transcondylar axis of the distal femur parallel to the floor and assist with rotational alignment during IM nailing of multifragmentary tibial fractures. External rotation of the limb is also prevented by using such a roll. Triangles, bumps made from sterile gowns, dropping the end of the table, and placing the leg over the side of the table may facilitate this degree of knee flexion. The use of a padded kidney rest at the lateral aspect of the proximal thigh, often at the level of the tourniquet can be used to maintain knee flexion and prevent external rotation of the hip in deep knee flexion (Fig. 2). Care must be taken not to place any pressure on the neurovascular bundle in the popliteal fossa.
PRINCIPLES, METHODS, SURGICAL ACCESS

Closed Reduction

Closed reduction should be attempted if the fracture is not over 10 days old. The reduction technique varies based on the level of the fracture. Proximal fractures may be reduced by using the Figure 4 position (Fig. 3) with emphasis placed on flexing the proximal fragment to 110 degrees. Flexing the proximal fragment in relation to the knee allows the tibial entry point to be placed in its appropriate position.

Determine the instability at the fracture site, taking into consideration the mechanism of injury and the x-ray appearance. Sometimes the unreduced fracture is stable in 1 direction but not in another. Palpate the fracture site, visualize the position and allow the operating surgeon to perform fracture reduction. More than 1 surgeon attempting to reduce the fracture does not work well. The surgeon must be allowed to focus on the reduction and not be rushed by the other surgeons who may be offering advice. This is especially true for the junior surgeon who is trying to concentrate. Each surgical procedure should be a learning process for all surgeons.

When using cannulated tibial nailing systems and image intensification, a “cheat lateral” x-ray of the distal tibia can be obtained efficiently without swinging the C-arm into a full lateral position. The “cheat lateral” simply requires the C-arm to be rotated 20 to 30 degrees away from the surgeon and fractured tibia. The operating table is rotated toward the surgeon 10 to 15 degrees, the leg is externally rotated 20 to 30
degrees and a few degrees of gentle external rotation at the fracture site allow the centering of the guide wire to be visualized on the lateral ankle view (Fig. 4). This maneuver avoids possible contamination of the set-up as the C-arm swings to a lateral position.

Significance: Each operating room has opportunities and limitations when performing closed reduction.

Incision and Proximal Tibial Entry Point

There are different recommendations regarding where the bone entrance point should be placed. In general, the more proximal the fracture, the more lateral the entry point should be. Some believe that the entry point should be medial to the lateral tibia spine. Anatomic dissections reveal the lateral meniscus to be at risk with a lateral parapatellar approach and care is required to avoid injury. Tornetta states that “the safe zone is located 9.1 millimeters lateral to the center of the plateau and 3 millimeters lateral to the center of the tibial tubercle.” The surgeon cannot use these landmarks without imaging. The patella tendon is palpated with the knee in flexion. A central longitudinal incision through the tendon allows a predictable and accurate placement of the bone entrance when an image intensifier is not used (Fig. 5). The fat pad should never be entered. The bony entrance is anterior to the articular surface (Fig. 6). A curved awl is used and is directed anteriorly, especially in a proximal tibia fracture (Fig. 7). Usually several passes of the awl provide a good pathway for the reamers.

A common error in proximal tibial fractures is to place the entry point too anteriorly. This results in the nail path coursing from proximal anterior to distal posterior in the proximal fragment resulting in a procurvatum deformity (Fig. 8). This frequently requires blocking screw placement to correct the malalignment. An anterior entry point also puts the patient at risk for anterior cortical bone loss as progressively larger diameter reamers remove anterior bone. This is especially true for pneumatic reaming and can be minimized by pushing the reamer head though the entry point and pulling the reamer head out without power. This is not a concern using the hand reamers (Fig. 9). Another common error is to use a medial parapatellar entry point for proximal tibial fractures which tends to result in nailing of the fracture in a valgus position. A transpatellar tendon approach is preferred and carries no increased risk of anterior knee pain. The reduction may also be achieved by means of knee flexion and placement of the limb in the “Figure 4” position (Fig. 10).
Significance: Incising the patella tendon longitudinally leads the surgeon to the proper bony entrance.

Reaming

Several studies have demonstrated a benefit to IM reaming in terms of improved union rates. The 7 to 9 mm SIGN hand reamers are pointed and should be rotated clockwise by the surgeon as the reamer head is advanced along the medullary canal of the distal fragment. The 10 to 15 mm reamers are blunt-tipped to prevent cortical perforation in osteoporotic bone. An additional benefit of these blunt reamers is that the length of the planned nail can be determined by passing the reamer tip until it reaches the physeal scar or subchondral bone at the ankle (Fig. 11). Markings on the large SIGN reamers may be used to determine the appropriate nail length.

After reduction, reaming is accomplished by starting with the 7 mm reamer and progressively increasing the diameter until chatter is felt for at least a 4 cm distance along the canal. The resistance to progression of the reamer is also an indicator. One should feel the reamer in its full 180 degrees arc to know the reamer is in the canal. If there is a question about whether the reamer is in the canal, push on it and see whether there is a stop. If not, the reamer is not in the canal. The length of the nail is measured by pushing the blunt reamer until it abuts the subchondral bone of the ankle joint. An x-ray of the opposite unfractured tibia may be used as a guide but is not as accurate as clinical estimates or reamer depth. The surgical team may check nail inventory preoperatively by estimating nail length using anthropometric measurements: tibial tuberosity to medial malleolus; joint line to medial malleolus; olecranon to head of fifth metacarpal; head distance or normal tibia from knee joint line to ankle joint line less 20 mm. The knee joint line to ankle joint line less 20 mm measurement is the most reliable and has shown the best correlation (0.982) with ideal nail lengths.

The bone from the flutes of the hand reamer should be retained if the fracture site has been opened. Store the bone in blood without contact with a sponge, normal saline or sterile water. Passing the reamers through the fracture site has been described in the reduction section. Care should be taken to avoid cortical heat necrosis by deflating the tourniquet during

FIGURE 8. A, Anteroposterior and lateral (B) views of a multifragmentary proximal tibial fracture in a 43-year-old woman. C, Lateral view showing the proposed skin incision marked under x-ray fluoroscopy with the tip of a knife blade centered within the handle of a hemostat. D, Drill insertion with the initial Kirschner wire defining the entry path of the nail. Note that the entry point is slightly distal than is ideal. This type of distal entry point will increase the need for proximal blocking screws. Screw insertion is noted on the lateral view (E) and on the anteroposterior view (F). As the intramedullary nail is inserted, the procurvatum deformity is seen on the lateral view (G) and alignment corrects on full IM nail seating (H). Photos courtesy of Dr. Mark Steeves and Dr. Steven Papp.
power reaming and a limited-ream approach is recommended for high-energy fractures. Heat necrosis and damage to the pulmonary system is negligible when hand reaming is used.

Significance: The advantage of hand reaming is that the surgeon can feel when the reamer is in the bone, measure the length and diameter of the nail from the reamers and use the bone from the flutes of the reamers for a bone graft.

The nail is then attached to the target arm, and the target arm is adjusted. The target arm is then removed and the locking bolt and L-handle are used to introduce the nail (Fig. 12). Reduction must be maintained during this process. The nail is placed either by direct pressure from the surgeon or by light taps using the mallet. The nail has a 1.5 degrees bend in the distal end and therefore the nail is twisted after each 3 taps. The surgeon soon becomes familiar with this feel when the nail is in the canal. Do not force the nail. Ream larger or use a smaller nail if the nail does not progress easily. The ring on the stem tube of the L-handle helps the surgeon decide the depth of the nail.

Significance: The surgeon’s tactile sense guides placement of the nail through the fracture site.

Distal Interlocking
Reattach the Target Arm
The target arm is reattached and the alignment pin used to dimple the skin. Interlocking screws are placed through the medial side of the tibia. If 2 screws are used, dimple the skin by passing the alignment pin through both apertures and connect the dots. Avoid injury to the saphenous vein and nerve (Fig. 13). Distal interlock should be done before proximal interlock to allow the nail to be rotated to adjust orientation of the slot for screw insertion. Reattach the target arm to the L-handle. Be sure the locking bolt connecting the L-handle to the nail is tightly secured.

Insert Cannula
Use the alignment pin to mark the location of the skin incision. Dissect the bone with a periosteal elevator to remove all soft tissues. Place the cannula through the incision down to the

FIGURE 9. Reaming. Always make sure that the fracture is reduced prior to passing the reamers.

FIGURE 10. A, “Figure 4” position. The knee is flexed and the hip externally rotated. B, This results in a varus force across the fracture site which will resist the tendency of a proximal tibial fracture to be nailed in valgus alignment.

FIGURE 11. The length of the planned nail can be determined by passing the hand reamer tip until it reaches the physeal scar or subchondral bone at the ankle.

FIGURE 12. A, “Figure 4” position. The knee is flexed and the hip externally rotated. B, This results in a varus force across the fracture site which will resist the tendency of a proximal tibial fracture to be nailed in valgus alignment.
bone using a clamp to spread and remove the soft tissues from under the cannula. Tight bands of tissue must not displace the cannula.

**Significance:** The cannula must rest directly on the bone.

**Drilling the Near Cortex**

Insert the small drill guide into the cannula. Drill a hole in the near cortex (Fig. 14) using the small drill bit. If the bone is hard, do not maintain persistent pressure on the drill. Pulsing the drill involves drilling for 10 seconds followed by withdrawal of the drill to allow it to cool. The drill bits become dull when heated. Change the small drill guide to the large drill guide and use the step drill to enlarge this hole. The large drill bit may also be used when the bone is too hard for the step drill. Stop immediately when the step drill engages the slot in the nail. The hole can now accommodate the slot finders and the threaded head of the screws.

**Significance:** Pulse the drill in hard bone and stop rotation when the step drill is in the slot of the nail.

**Insert Solid Slot Finder**

The solid slot finder is used to find the slot in the nail (Fig. 15). Insert the solid slot finder into the cannula. The solid slot finder is stronger and has a narrower tip than the cannulated slot finder. The solid slot finder is aligned using the flat portion of the handle with the plane of the nail. It is then pushed into the slot in the nail. It is not placed by rotation. The “SIGN feel” can be demonstrated when the slot is in the nail (i.e., 10 degrees rotation either way). If the slot finder does not rotate at all it is only partially inserted into the slot in the nail so rotate the nail using the L-handle. If the slot finder rotates 360 degrees, it is not in the slot, rotate the nail to help find the slot finder in the slot.

If the solid slot finder does not enter the slot in the nail, there may be bone either in the near cortex hole or in the slot in the nail, or the hole may be maldirected. Use the screw hole broach to clear the hole. If the slot finder rotates more than 20 degrees, it is not in the slot of the nail. If the slot finder does not rotate at all, it has been placed obliquely through the slot of the nail. Rotate the nail, so the slot finder will be inserted properly into the slot of the nail. After the slot finder enters the slot in the nail replace it with the cannulated slot finder. Once the cannulated slot finder has been placed through the slot of the nail, the drill bit is placed through it and the hole drilled in the far cortex (Fig. 16). SIGN drill bits are not disposable, hence it is important that the tips do not hit metal. When a notch or defect is placed in a drill bit tip, the drill heats up and becomes dull very quickly.

**Distal Interlocking Tips**

Reasons why the slot finder may not enter the slot in the nail:

1. The hole in the near cortex has been incompletely drilled and therefore the screw hole broach is needed to remove the rim of bone at the bottom of the hole.
2. The reduction has been lost and the bone has shifted after the nail was inserted.
3. The most common cause of failure to locate the slot is rotation of the nail on the insertion handle due to loosening of the locking bolt within the threads of the proximal end of the nail. Be sure that the locking bolt is tightened before attempting interlock. Use the same principle as when using...
a C-arm. The surgeon lines up the 2 apertures so they are parallel. Once the surgeon understands the value of rotation, distal interlocking without a C-arm is very quick and reliable. Sometimes this rotation must be accounted for by using the curved slot finder. The target arm is removed and a curved slot finder placed into the slot. If it is placed only partially in the slot, rotate the nail for complete placement in the slot. The curved slot finder is then replaced by the cannulated slot finder.

4. The nail has been bent by a tight tibial canal. This will occur if heavy blows are used to strike the nail. Two or 3 light taps and then a 20 degree twist of the nail is the proper technique.

Significance: The target arm guides longitudinal placement of the screw hole in the transverse direction. Rotation of the nail facilitates placement of the slot finders in the distal slot in the nail. This technique is reliable and efficient.

Measure for Screw Length and Insert Screw
The depth gauge is placed through the cannulated slot finder and left in place as the slot finder and drill guide are removed (Fig. 17). The depth gauge is calibrated to be read off the side of the cannula. We add 2 or 3 mm so the proximal end of the screw can be left slightly prominent in case removal is required at a late date. Keep the cannula over the hole in the near cortex and then push the screw through the hole in the near cortex and slot in the nail. The surgeon will feel the screw threads pass through the slot and engage in the far cortex. Determine whether the distal interlocking screw is through the slot in the nail by rotating the L-handle. If the screw is in the slot, the nail can be rotated 10 degrees. Pull the cannula back to visualize the head of the locking screw to be sure it is not inserted too far into the near cortex. This is a risk when locking screws are inserted in osteoporotic bone.

The alignment pin is placed through the hex hole in the head of the screw to align the target arm for placement of a second distal interlocking screw (Fig. 18). The surgeon must decide whether 1 or 2 screws is necessary. This depends on the stability of the fracture, distance from the slot to the fracture site, and location of the fracture.

Compression of the Fracture
Once the distal interlocking screw or screws have been placed, the fracture may be compressed, if necessary. This is accomplished by attaching the extractor-compressor rod containing the weight and backslapping the fracture (Fig. 19). This is particularly important in the treatment of tibial nonunion. Make sure that the IM nail has been countersunk into bone of the proximal tibia when backslapping is being considered. This
will prevent prominence of the proximal nail and difficulties with kneeling. Similarly, if the tibial fracture remains overlapped and shortened, it can be lengthened at the fracture site by performing distal interlocking, further impaction of the nail followed by proximal interlocking.

**Significance:** The extractor-compressor is used after distal interlocking to compress or lengthen the fracture site.

The number of screws decreases as the surgeon becomes more confident in the SIGN system. Clinical results have shown that 1 distal locking screw has been sufficient on many occasions. The fact that there are threads in the near and far cortex for fixation of the screws may provide more stability. Clinical results from the SIGN database have yielded a very low incidence of broken locking screws. If 1 distal locking screw is used, it should be placed in the proximal slot.

**Placement of the Proximal Interlocking Screw**

The target arm is replaced if it has been removed and should be firmly attached to the L-handle. Insert the alignment pin tip to the skin surface to mark the location of the skin incision. Incise the skin and clear soft tissue off the bone. Insert the cannula onto the bone of the medial tibial surface. Use the cannula, small drill guide and small drill bit to drill a hole through the near and far cortices. Note that the slot finder is not
necessary to find the nail slot for proximal interlock. The holes are enlarged using the step drill and the interlocking screw placed using the usual measurement and insertion process (Fig. 20). The placement of 2 screws in the proximal tibia is recommended. This is not always followed by all SIGN surgeons and is an area in need of future study.

Significance: The slot finders are not used to find the slot and hole in the proximal nail.

Wound Closure
The incision through the patellar tendon is closed first. Only the tendon sheath needs be closed. The wound over the fracture is closed. Placing drains has been a common practice in developing countries but is not recommended. A 2007 Cochrane database review noted: “Pooling of (multiple study)

results indicated no statistically significant difference in the incidence of wound infection, hematoma, dehiscence or reoperations between those allocated to drains and the undrained wounds. Blood transfusion was required more frequently in those who received drains. The need for reinforcement of wound dressings and the occurrence of bruising were more common in the group without drains. There is insufficient evidence from randomized trials to support the routine use of closed suction drainage in orthopaedic surgery.”

Aftercare
In stable fractures, early weight-bearing as tolerated is recommended. Weight-bearing is determined by the stability of the fracture. The time to full weight-bearing is significantly delayed in high-energy and open fractures.
Open Reduction for Closed Fractures

If closed reduction is not possible after a short time, a small incision for open reduction can be made. This is made just over the fracture site on the anterolateral side. A periosteal elevator can align the bone canals. It requires concentration and careful planning for the surgeon to use a small, appropriately placed open reduction incision. Palpate the fracture site and determine whether there is any overlapping of the fragments. In this situation, palpate the distal end of the proximal fragment, place the incision at this site and use a periosteal elevator to bluntly reflect muscle fibers laterally and dissect down to the fracture site. Most trauma surgeons recommend an anterior incision placed 1 to 2 cm lateral to the crest of the tibia and pulling the anterior compartment muscles laterally to expose the fracture site. Use of cutting electrocautery or a knife to cut through muscle is not recommended.

After the end of one of the fracture fragments has been identified, dissect the callus and scar circumferentially to allow mobilization of this fragment. Find the other bony fragment and do likewise. Once these fragments have been freed up, place a bone clamp on both sides of the fracture site and allow the distal fragment to flex 90 degrees. Hook the posterior cortex of both fragments and gradually extend the fragments at the fracture site. Care is sometimes required to wait for the tissues to slowly stretch out to length as the fracture site is extended.

FIGURE 18. The alignment pin is placed through the hex hole in the head of the screw to align the target arm for placement of a second distal interlocking screw.

FIGURE 19. Compress the fracture by attaching the extractor compressor and weighted rod and backslapping the fracture. The IM nail must be countersunk into the proximal tibia if backslapping is being considered to prevent prominence of the proximal nail and difficulties with kneeling.

FIGURE 20. Proximal locking screw insertion. The slot finder is not necessary for proximal interlocking. Use the small drill bit (A). The holes are enlarged using the step drill (B).
Sometimes a periosteal elevator must be placed between these fragments to stretch the tissues for the last 1 cm of length. One possible obstruction can be the eager assistant who attempts to apply traction without flexing at the fracture site.

Reduction must be maintained during reaming and insertion of the nail. A Loman or Verbrugge clamp is ideal for this. If the fracture is oblique, the ends can be approximated and pressure applied to slide the bones together. One surgeon should be assigned the task of being sure reduction has been maintained. This is essential after the hole in the near cortex has been drilled for placement of distal interlock. If the loss of reduction goes unnoticed, the location of the slot in the nail will be significantly delayed.

Proximal tibial fractures require care with respect to appropriate reduction and prevention of valgus and procurvatum deformity. An open reduction may be required for a fresh proximal tibial fracture if there is a tendency for the fracture to fall into either or both of these positions. Nork recommends using unicortical screw fixation and small fragment plates during limited open reduction of the fracture. Once the fracture is anatomically aligned, the IM nailing can then proceed in a more controlled manner. Flexing the proximal fragment in relation to the femur is very important. Some surgeons prefer to flex the proximal fragment using the Figure 4 position. Check the rotational alignment of the tibia once the tibial nail has been fully seated.

SPECIAL CONSIDERATIONS

Open Fractures

Open fracture wounds must be continually evaluated by the operating surgeon. The first step is to assess the damage to the soft tissues, which often extends past the opening in the skin. Foreign bodies, dead muscle, dead bone, and soft tissue must be removed. Copious irrigation continues as long as foreign material and dead tissue flow out of the wound. If the fracture is multifragmentary, small bony fragments without muscle attachment are removed. Avoid soft-tissue stripping of fracture fragments. High-pressure irrigation systems may force bacteria back into the tissues and these bacteria will emerge later and cause infection. The location where the injury occurred may also add bacteria as in the classic “barnyard injury.” Appropriate antibiotics are given for these.

The most important decision the surgeon will make is whether the wound can be loosely closed after debridment and the nail inserted. If the wound is deemed clean enough to close without a great deal of dead space, the nail can be inserted. Placing external fixation for 10 days prior to nail insertion is used more frequently in North America because of greater access to resources. Consider temporary external fixation for grossly contaminated open fracture wounds or those patients requiring damage control orthopaedics. Early conversion to IM nail is best and contra-indicated in patients with a recent pin-site infection or wound infection. The infection rate has been linked with the time the external fixation has been in place, as well as the interval between removal of the external fixator and placement of the IM nail with a delay of greater than 14 days offering an advantage in terms of infection.

Temporary external fixation is not as practical in developing countries because of expense and operating room availability. We are studying these decision trees on our database. If the wound is clean and can be debrided and irrigated within 6 to 12 hours of injury, nail fixation can be performed. If definitive wound closure is not recommended at the time of nail fixation, bacteria that cause infection are introduced during the hospitalization. An important yet very simple method of preventing multiply-resistant nursing ward bacteria from entering the open fracture wound is to apply an antibiotic bead pouch. An antibiotic bead pouch can decrease the risk of hospital-acquired infection 4-fold and involves the use of an occlusive plastic dressing. The wound remains moist and antibiotics leak from the beads into the serosanguinous fluid which is trapped by the occlusive dressing. The dressing is changed only in the operating theater under strict aseptic technique (Fig. 21). If antibiotic beads are not available, simply wrapping the open fracture wound with an occlusive sterile clear plastic dressing will also keep multiply drug-resistant ward bacteria from entering the wound. No gauze is used. Negative pressure wound therapy can also be used.

Wound closure should be performed as early as possible. If there is a great deal of muscle debridement and exposed bone, a muscle flap is usually required. The timing of the skin grafting of this muscle flap depends on surgical experience and availability of operating time. The earlier a wound can be closed the better. Godina demonstrated a much lower flap failure rate, lower infection rate, shorter hospitalization, fewer operative procedures, and much more rapid healing time for tibial fractures treated by microsurgical reconstruction within 72 hours of injury. The flap failure rate was 0.75% when performed earlier than 72 hours following injury but 12% when carried out at 3 days to 3 months. After 3 to 4 days it becomes more difficult to discern between the “zone of injury” and healthy recipient vessels. Recipient vessels lying within the zone of injury have activated platelets adherent to their intimal surfaces and the rate of postoperative anastomotic thrombosis is much higher. The infection rate for the early flap coverage

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group was only 1.5% in Godina’s early coverage group (P < 0.0005).

Significance: Definitive wound closure and stabilization of open fractures should be accomplished as soon as possible after the initial debridement is completed.

Distal Tibial Metaphyseal Fractures
Distal tibial metaphyseal fractures remain a significant treatment challenge. Preoperative x-rays should be carefully inspected to rule out intra-articular extension. Such extension is not a contraindication to IM rod fixation but it is important to identify an undisplaced fracture and place a peri-articular lag screw across it before proceeding with rod fixation. There is no universal agreement with respect to distal fibular fixation. Some surgeons prefer to fix the distal fibular fracture first using AO technique, lag screw fixation and neutralization plating.37 Their rationale is that the tibial fracture then becomes a much more simple and controlled IM nailing. When the distal fibula is fixed first, there is less concern about valgus alignment of the tibia because of fibular shortening and overlap.38 If the fibular is overlapped, the ankle joint will be in valgus and plating of the fibula is recommended. The fibula may also be plated when additional stability is necessary. Another decision relates to the use of the distal IM rod to stabilize the fibula. This situation works effectively for fibular fractures involving the proximal two-thirds. For distal tibial fractures, particularly in osteoporotic bone with a wide medullary canal, medial and lateral anteroposterior blocking screws provide additional stability to varius-valgus displacement in the coronal plane. This is especially important for distal tibial fractures where there is room for only 1 distal tibial interlocking screw.

Significance: Guidelines for stabilization of the fibula have not yet been clearly defined.

Blocking (Poller) Screws
When the fracture is in the proximal tibia, especially when the fracture line extends higher on the posterior cortex, a blocking screw may be used.39,40 The blocking screw is placed from the medial side (Fig. 22). It is important to remember the anatomy of the peroneal nerve on the lateral side. After the drill has been placed through both the medial and lateral cortex, use a hemostat and pass it through the entry point to determine whether the drill has entered the reamed canal. If it has, place the blocking screw more posteriorly. The blocking screw can also be used for varus–valgus orientation of the nail. This is often used when the fracture is oblique in the medial–lateral plane. Remember the blocking screw is placed where the surgeon does not want the nail to go. If the fracture is diagrammed on a piece of paper before surgery, placement will be automatic.

Significance: Remember that the blocking screw should be placed on the concave side of the deformity that is being noted in the operating theater.
For a varus procurvatum deformity of the distal tibia, the blocking screws will be placed medially and posteriorly (Fig. 23). In the distal tibia, the tibia medullary canal flares considerably and the addition of blocking screws will also increase the strength and rigidity of the fixation. Also, when there is a butterfly fragment or absence of cortex on 1 side of the distal tibia, the nail may wander through this opening. A blocking screw can be more easily placed in the distal fragment because there is more room for the screw in the flare of the tibial metaphysis (Fig. 23). Krettek’s initial experience with 21 tibial fractures involved the management of 10 proximal and 11 distal tibial fractures. All fractures healed at a mean of 5.4 months. The mean alignment was 1 degree of valgus (range: 5 degrees valgus to 3 degrees varus) and mean procurvatum 1.6 degrees (range: 6 degrees recurvatum to 11 degrees procurvatum).

Segmental Bone Loss
For most patients who have sustained segmental bone loss, associated injury to the soft-tissue envelope will require free flap coverage at the time of definitive wound closure. Rotation flap coverage may sometimes be suitable for smaller, more proximal defects or when the overall condition of the patient is less favorable. If IM nail reconstruction is selected for management of a segmental defect, the amount of autologous cancellous bone graft that will be required should be carefully calculated. The posterior iliac crest provides up to 40 mL of cancellous autograft compared with 10 to 15 mL for the anterior crest. Using the bone from the flutes of the hand reamer can yield a significant quantity of bone suitable for butterfly defects or short segmental defects during open reduction. If the defect exceeds the amount of available autograft, options include: allograft cancellous bone or transport over the IM nail. Free vascularized fibula reconstruction and Ilizarov bone transport in the absence of an IM nail are other treatment options. The glycolylic (biofilm) that forms around dead bone and metal and harbors bacteria is different than the biologic membrane that forms around methylmethacrylate. Methylmethacrylate can be used as a spacer to maintain a pocket which will later be replaced with autogenous cancellous graft. When the methylmethacrylate spacer is removed and bone graft inserted, bone formation is stimulated by the biologic membrane.

Indications for Nail Removal and Anterior Knee Pain
The tibial IM nail may be removed once the fracture has remodeled solidly, usually 18 to 24 months after fracture healing. In the experience of Court-Brown, knee pain resolved in 27% and marked improvement was observed in 69% following tibial nail removal. Knee pain was worsened in 3% of patients. However, Buckley observed a 14% incidence of worsening of knee pain with nail removal. No difference in knee pain has been observed for the tendon sparing approach versus transpatellar tendon approaches.

CONCLUSION
Fractures of the tibia can be managed by SIGN IM nail interlocking screw system in developing countries. The entry point is an important aspect of achieving accurate restoration of alignment. The fracture site should not be nailed in a distracted position. If distraction is observed, back-slapping the nail will improve bone apposition. If fluoroscopy is not used for the procedure, and the fracture site is noted to be distracted on postoperative x-rays, either revision surgery or early nail dynamization should be considered. Definitive wound closure of open fracture wounds should be achieved as soon as possible after the initial debridement surgery usually by 3 to 7 days. Leave grossly contaminated wounds open and covered with an antibiotic bead pouch whether in doubt and perform repeat debridement 24 to 36 hours later. Segmental bone loss can be managed most commonly by autogenous iliac crest bone grafting although more sophisticated techniques such as bone transport are occasionally required.

REFERENCES