Review Article

Modern Principles in the Acute Surgical Management of Open Distal Tibial Fractures

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ABSTRACT

Over the past two decades, management of open distal tibial fractures has evolved such that a staged approach, with external fixation and débridement during the index procedure, followed by definitive fixation and wound closure at a later date, is often considered the standard of care. Although definitive treatment of these complex injuries is often done by a multidisciplinary team of surgeons well versed in periarticular fracture repair and soft-tissue coverage in the distal extremity, the on-call orthopaedic surgeon doing the index procedure must understand the principles and rationale of the staged treatment algorithm to avoid compromising definitive treatment options and ensure the best possible patient outcome. The mechanism of injury, neurovascular status, size and location of soft-tissue injury, fracture pattern, and concomitant injuries in the polytraumatized patient should direct the treatment plan and anticipated outcomes. This review focuses on evaluation and management of these complex injuries with an emphasis on early aggressive débridement, principles of initial fracture fixation, and modern options for soft-tissue coverage, including local and free tissue transfer.

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None of the following authors or any immediate family member has received anything of value from or has stock or stock options held in a commercial company or institution related directly or indirectly to the subject of this article: Shafiq, Hacquebord, Wright, and Gupta.

J Am Acad Orthop Surg 2021;29:e536-e547

DOI: 10.5435/JAAOS-D-20-00502

Open tibial fractures account for 11.2% of all open fractures and represent a significant source of morbidity and economic cost burden.[1] Although basic principles of management have remained constant since Gustilo and Anderson described the importance of early antibiotic administration and aggressive surgical débridement, advances in our understanding of fracture biology, fracture fixation, and microsurgical technique have changed the landscape of both routine management and complex limb salvage over the past 20 years. A staged approach, with the index procedure including external fixation and debridement, followed by definitive fixation and wound closure at a later date, is often considered the standard of care. Although definitive treatment is often done by a multidisciplinary team of surgeons well versed in periarticular fracture repair and soft-tissue coverage in the distal extremity, the on-call orthopaedic surgeon doing the index procedure must understand the principles and rationale of the staged treatment algorithm to avoid compromising definitive treatment options and ensure the best possible patient outcomes. Although this review focuses specifically on the initial management of open distal tibial fractures, many of the principles can also be applied to closed injuries.

Initial Management

Open distal tibial fractures have a bimodal distribution, occurring because of high-energy trauma in young patients or lower-energy falls in the elder patients.[1] In cases of high-energy trauma, evaluation by a multidisciplinary team should proceed according to advanced trauma life-support protocols. Soft-tissue injury and limb deformity associated with these fractures can be impressive and often distracts both the patient and physician from recognizing other notable injuries, obtaining a detailed history, and doing a thorough physical examination. Details about the mechanism of injury, wound contamination, and associated injuries help guide initial management, plan definitive fixation, and direct shared decision-making that will determine the ultimate goals of treatment in these life-altering injuries. Other important elements of the history include age, premorbid functional status, comorbidities, medications, and social history (including smoking status) that may impair wound healing or increase the risk of infection.

Physical examination includes inspection to identify the location, size, and orientation (transverse, longitudinal, and stellate) of the open wound(s) in addition to characterizing the types of soft tissue involved (skin, fat, fascia, muscle, tendon, nerve, vessels, and bone). Palpation of the entire limb should follow because the incidence of associated lower extremity fracture and other major system injuries ranges from 27% to 51%.[2] Open fractures do not preclude the development of acute compartment syndrome, and a high index of suspicion is imperative for diagnosis, especially in the obtunded patient. Acute compartment syndrome will develop in 1.4% to 5% of distal tibial fractures and should be managed expeditiously.[3] Once an open fracture is identified, antibiotics and tetanus vaccine should be administered as soon as possible.[4] Patzakis demonstrated that delay in antibiotic administration more than 3 hours after injury resulted in 1.63 greater odds of infection, whereas Lack more recently showed that administration more than 66 minutes after injury was associated with a 3.78 greater odds of infection.[4,5]

The neurovascular examination is the most critical component of the initial examination. Hard signs of vascular injury include absent or asymmetric pulses, severe hemorrhage, and expanding hematoma. In the absence of distal pulses or when signs of hypoperfusion are present, gentle reduction with longitudinal traction should be done, followed by repeat vascular examination. If pulses remain absent, doppler examination is indicated to confirm the presence or absence of signals. Although ankle brachial index <0.90 is suggestive of vascular injury, doing such an examination in the presence of an open distal tibial fracture is often not feasible.[6] If repeated examination remains abnormal, CT angiogram or formal on-table angiogram is warranted. In patients with active hemorrhage, attempts to clamp or ligate a bleeding vessel in the trauma bay are contraindicated because this can result in injury to adjacent neurovascular structures (ie, tibial nerve), leading to permanent neurologic deficit and hindering subsequent efforts for limb salvage. At the distal tibia, even notable arterial bleeding can often be controlled by direct pressure, followed by application of a compression dressing. Even if the initial vascular examination is normal, serial examinations should be done because intimal tears or flaps within larger arteries may subsequently thrombose, resulting in delayed presentation of a dysvascular extremity. One study of high-energy tibial plafond fractures identified a 52% incidence of arterial abnormalities including 7 with complete arterial occlusion, 2 with partial occlusion, and 5 with normal flow but with anatomic disturbances (4 tented and 1 entrapped by fracture fragments), with a significant association between open fracture and arterial abnormality.[7] Associated arterial injury is a risk factor for flap failure at the time of reconstruction and may impact the choice of surgical approach and soft-tissue reconstruction.

Imaging should consist of dedicated AP, lateral, and mortise views of the ankle and foot and full-length AP and lateral views of the tibia and fibula. In fractures with notable intra-articular comminution, CT is best done after external fixation, once basic length, alignment, and rotation have been restored. However, early CT imaging before external fixation is appropriate when there is minimal articular comminution or in distal third spiral tibial shaft fractures with question of intra-articular extension, which occurs in 39% to 92.3% of such fractures.[8,9] CT is also indicated before the index procedure if planning for limited internal fibular fixation or if immediate definitive fixation is an option. In such cases, CT helps delineate fracture planes that will guide surgical approaches and determine whether acute fibular open reduction and internal fixation (ORIF) will help or hinder the staged definitive fixation. If free or local tissue transfer is required, a CT angiogram or formal angiogram is indicated to identify potential recipient vessels for microvascular anastomosis and to identify anatomic variants including anomalous trifurcation of the popliteal artery, which has an incidence of 7% to 12%.[10]

Classification of Open Fractures

Classification of open fractures has evolved since the Gustilo-Anderson classification was first introduced in 1976. Although their work established that early antibiotic delivery and aggressive débridement were fundamental to open fracture care, the classification served mainly as a prognostic indicator, with types I, II, and IIIA having relatively low rates of infection and amputation, IIIB fractures having a 52% infection and 16% amputation rate, and IIIC having a 42% infection and 42% amputation rate in their original series.[11] Final classification is assigned after operative débridement and, therefore, provides little guidance regarding initial surgical management apart from appropriate antibiotic selection. Furthermore, type IIIB fractures encompass a wide range of soft-tissue injures, requiring procedures ranging from local soft-tissue rearrangement to free tissue transfer.

Recent classifications have sought to better describe different characteristics of the injury and provide guidance for treatment. The Ganga Hospital Open Injury Score (GHOIS) and the Orthopaedic Trauma Association Open Fracture Classification (OTA-OFC) systems are two such examples.[12,13] These classifications assign individual scores according to the degree of skin, muscle, nerve, bone, and arterial injury and also account for the degree of contamination (OTA-OFC) or patient comorbidities (GHOIS). Subsequent studies of these scoring systems have demonstrated their utility in guiding management. In a retrospective review of 109 patients with type IIIA and IIIB open tibial fractures, Rajasekaran[12] demonstrated that all fractures with GHOIS score <14 were successfully salvaged, whereas all of those with score >17 required amputation. Another study found that classification according to the OTA-OFC was predictive of early amputation with odds ratios of 3.4, 4.8, and 6.5 for severity of skin injury, arterial injury, and degree of contamination, respectively.[13] Because associated soft-tissue injury, neurovascular injury, and patient comorbidities have increasingly been recognized as critical predictors of outcomes after open distal tibial fractures, classification schemes have shifted focus to account for these factors in an effort to better guide surgical management.

Timing of Surgery

In the absence of arterial injury, initial surgical management for open distal tibial fractures should ideally be done within the first 24 hours after injury. Historically, open fractures have been considered an "orthopaedic emergency" warranting débridement within 6 hours of injury. This "6-hour" rule was based largely on clinical opinion and animal/bacteriology studies conducted before the consistent delivery of modern antibiotics.[14] Recent studies have demonstrated little or no difference in infection rates between fractures débrided within 6 hours or within 24 hours as long as antibiotic management was initiated early.[15] Associated life-threatening injuries, hemodynamic stability, and adequacy of resuscitation should also be considered before proceeding with index débridement and stabilization.

The concept of staged management of distal tibial fractures was first introduced independently in separate studies by Sirkin and Patterson.[16,17] Previous studies had identified high rates of wound complications and infection in up to 40% of patients when ORIF was done 3 to 5 days after injury.[18,19] By contrast, using a staged protocol, Sirkin found an overall infection rate of 5.3% in their series of 56 patients with either open or closed distal tibial fractures, whereas Patterson noted a 0% rate of deep or superficial infections in their series of 22 type III open distal tibial fractures.[16,17] These results highlighted the importance of appropriate soft-tissue management. More recently, several retrospective studies have advocated for early ORIF in select patients with appropriate soft-tissue envelope.[20-22] In their retrospective cohort study of 95 patients treated with early ORIF (within 48 hours of injury), White et al reported a 19% infection rate in open fractures and a 2.7% infection rate in closed fractures. Of note, four patients were excluded from the study because of "local soft-tissue" factors necessitating the placement of temporizing external fixation at the discretion of the treating surgeon.[22] Meanwhile, Tang et al[20] compared early (<36 hours) versus late (10-21 days) ORIF of closed C-type pilon fractures and found no difference in the rate of soft-tissue complications between groups with a significantly shorter hospital stay and time to fracture union in the "early" group. Overall, recent studies have, at best, shown no difference in infection rates between early definitive and staged fixation groups.

Principles of Débridement

Early, aggressive débridement is the foundation of surgical management for open distal tibial fractures. The primary goal during débridement is removal of all foreign debris and nonviable tissue to establish a clean, healthy wound. This should be done without concern for the ease of reconstruction. The quality of débridement is the most critical surgeon-controlled factor in the prevention of infection and limb preservation because subsequent reconstructive efforts will prove futile if an inadequate débridement is done. Débridement should be approached in a systematic fashion beginning with skin, subcutaneous tissue, fascia, muscle, tendon, and finally bone. The most experienced surgeon available should guide the débridement because assessing tissue viability is often the most critical and challenging portion of the case. Every débridement should begin with extension of the wound to allow for adequate inspection of deeper tissues. Incisions should be extended in a longitudinal fashion with an effort to incorporate transverse or oblique traumatic wounds in a curvilinear fashion. Incisions directly over the subcutaneous border of the tibia should be avoided because this is the most challenging area to achieve subsequent soft-tissue coverage. Incision length should match the degree of contamination and mechanism of injury, with a larger exposure required for more severe injuries. Débridement of skin and subcutaneous tissue should be done without the use of tourniquet because soft-tissue viability can be determined based on the presence of punctate bleeding. Muscle viability is often assessed with the use of the 4 Cs: contractility, color, consistency, and capacity for bleeding. Muscle of questionable viability should be excised because necrotic muscle serves as an ideal medium for bacterial growth. The decision to retain or remove the bone depends on vascularity and whether the fragment is diaphyseal, metaphyseal, or articular. In general, diaphyseal bone without evidence of bleeding and minimal soft-tissue attachment should be removed because these fragments can serve as a source of infection and the residual diaphyseal defects can be managed more easily than metaphyseal or articular defects. Metaphyseal bone has a higher capacity for revascularization and should be retained if not grossly contaminated. All efforts should be made to retain articular fragments. In cases in which tissues of questionable viability are retained, a second look débridement is mandated for reassessment of these tissues before proceeding with reconstructive efforts. In severely contaminated wounds with significant soft-tissue injury, several trips to the surgical room may be required before an adequate débridement has been achieved.

Principles of External Fixation

Skeletal stability is the next critical step after débridement during the index procedure. Key objectives include restoration of tibial and fibular length, coaxial reduction of the talus under the longitudinal axis of the tibia in coronal and sagittal planes, and prevention of equinus deformity. An ankle-spanning external fixator is often the best option for achieving these goals while providing temporizing fixation until the soft tissue is amenable to definitive fixation. Configurations include a biplanar triangular frame or a medially based unilateral fixator (Figure 1). Laterally based tibial pins are discouraged because the deep peroneal nerve and anterior tibial artery course in a distal-anterior direction away from the interosseous membrane between 40 and 110 mm proximal to the plafond, placing these structures at high risk during lateral pin insertion.[23] Care should also be taken when placing direct medial pins because overpenetration of the posterolateral cortex during drilling or pin insertion risks damaging the anterior neurovascular structures because they course along the interosseous membrane more proximally. In the triangular frame, two half-pins are placed in the tibial diaphysis and connected to a transfixing calcaneal pin, forming a biplanar construct. An additional pin can be placed in the base of the first metatarsal, the cuneiforms, or the cuboid to maintain the foot in a neutral position. A medially based unilateral fixator can be useful when the fracture morphology calls for prone positioning during definitive fixation. In this configuration, two half-pins are placed medially in the tibia and one half-pin is placed medially in the calcaneal tuberosity. In both constructs, the tibial pins should be placed well proximal to the anticipated proximal extent of the internal fixation construct. This avoids the theoretical risk of subsequent hardware infection via overlying open pin tracts or creation of a stress riser immediately adjacent to the terminal extent of the construct. Optimal fixation at the pin-bone interface is the most critical factor in establishing a stable external fixation construct and limiting the risk of pin-tract infection. This can be maximized using predrilling with irrigation and avoidance of eccentric pin placement. Applying self-drilling half pins in dense cortical bone without predrilling can result in thermal necrosis, stripping of the near cortex as the self-drilling screw spins to cut the far cortex, and

Figure 1

Figure demonstrating the common configurations for external fixation of distal tibial fractures include a biplanar triangular frame (**A**) or a medially-based unilateral fixator (**B**).

prominence at the far cortex to achieve full thread purchase, which may result in adjacent soft-tissue injury.[24,25] Once the provisional frame has been assembled, indirect reduction can be done by manipulation of the calcaneal-transfixing pin. The crossbar trajectory from proximal anterior to distal posterior in the triangular frame commonly results in an apex-anterior deformity at the fracture if simple longitudinal traction is applied. This can be minimized with anterior translation of the foot during reduction. Finally, although there is debate surrounding acute ORIF of the fibula to provide accurate restoration of length and more rigid fixation during the index procedure, it is recommended that ORIF of the fibula be done by the surgeon who will also be completing the definitive fixation because incisions must be carefully planned to avoid a skin bridge less than 5 to 6 cm.[26]

Initial Wound Management

Lacerations without notable underlying soft-tissue injury can often be closed primarily after a thorough débridement and skeletal stabilization. More severe injury to the skin and underlying tissues may require delayed wound closure, local soft-tissue rearrangement, or free tissue transfer. Accordingly, the traumatic wound is commonly temporized by application of negative pressure wound therapy (NPWT) or antibiotic bead pouch.

An evidence-based consensus statement on the use of NPWT in the management of open fractures provided a "Grade B" recommendation that "NPWT should be considered when primary closure is not possible after or between debridements as a bridge to definitive closure." This recommendation was based on several level II and level III studies and one level I study demonstrating decreased rates of infection in the NPWT group compared with wounds treated without NPWT.[27] The statement also provided a "Grade C" recommendation that "NPWT may be used to downscale the complexity of closure procedures" based on several level II studies demonstrating a decreased number of flap procedures with corresponding increase in split-thickness skin grafting for coverage of wounds after open fracture.

Polyvinyl alcohol (white) sponges are placed over areas of exposed tendon and bone deep within the wound because the pore size in these sponges is small (60-270 μm) and the material is hydrophobic compared with standard polyurethane ether (black) sponges (400-600 μm, hydrophilic), thereby decreasing the amount of tissue ingrowth and adherence during removal. A polyurethane ether sponge can then be placed over the polyvinyl alcohol sponge and covered with commercial adhesive dressings or iodoform-impregnated drapes. The sponges should never be placed directly over neurovascular structures because this can result in nerve injury or severe hemorrhage resulting in death in rare cases. If exposed, nonbraided suture can be used to pull local muscle or other soft tissue over these structures before sponge application. If the neurovascular bundle remains exposed, acute flap coverage should be considered. Alternatively, a non-adherent (ie, petroleum-based gauze) dressing can be placed over the wound, followed by wet to dry dressings. Animal studies have demonstrated that the greatest increase in granulation tissue occurs with negative 125 mmHg of intermittent suction for alternating cycles of 5 minutes on 2 minutes off.[28] However, continuous therapy can also be used and has been shown to increase granulation tissue as well.[28,29] Local antibiotic delivery through antibiotic impregnated polymethlmethacrylate (PMMA) cement has become common practice and can be used in conjunction with NPWT. In a 2014 systematic review, the addition of antibiotic beads to IV antibiotics in type III open tibial fractures treated with intramedullary nailing resulted in a substantial decrease in infection when compared with IV antibiotics alone (14.4% vs 2.4%).[30] However, the effectiveness of antibiotic beads is decreased when applied in combination with NPWT.[31] Modification of the antibiotic delivery to an antibiotic chitosan sponge when used with NPWT demonstrated improved results in an animal study and did not seem to decrease the effectiveness of antibiotic delivery.[32]

In addition, the antibiotic bead pouch is a technique preferred by some surgeons for initial wound management of open fractures. The technique involves use of antibiotic-impregnated PMMA cement "beads" placed into the traumatic wound with a plan to return to the surgical room for bead removal and staged wound management. In their review of local antibiotic therapy in treatment of open fractures, Zalavras et al[33] suggested the following antimicrobial dosing (grams of antibiotic powder per 40 g of PMMA cement): tobramycin (3.6 g), vancomycin (4 g), cefepime (4 g), cefazolin (6 g), nafcillin (6 g), and imipenem (4 g). The antibiotic and cement powders are mixed before adding the catalyzing liquid monomer. "Beads" are then rolled by hand to a size between 5 and 10 mm to maximize surface area and elution properties. Before final hardening, they are strung together on a length of nonabsorbable suture or 24-gauge wire for ease of later removal. A commercially available impermeable dressing such as and adhesive iodine dressing or adhesive plastic dressing can then be placed over the wound to create a sealed environment. It is recommended that the patient return to the surgical room within 48 to 72 hours for second stage débridement and replacement of the bead pouch versus primary or flap closure as indicated.[34] Bead pouches should be considered in the presence of notable gross contamination, extensive areas of exposed bone, or when exposed underlying structures such as nerves or vessels prevent the use of NPWT (Figures 2–5).

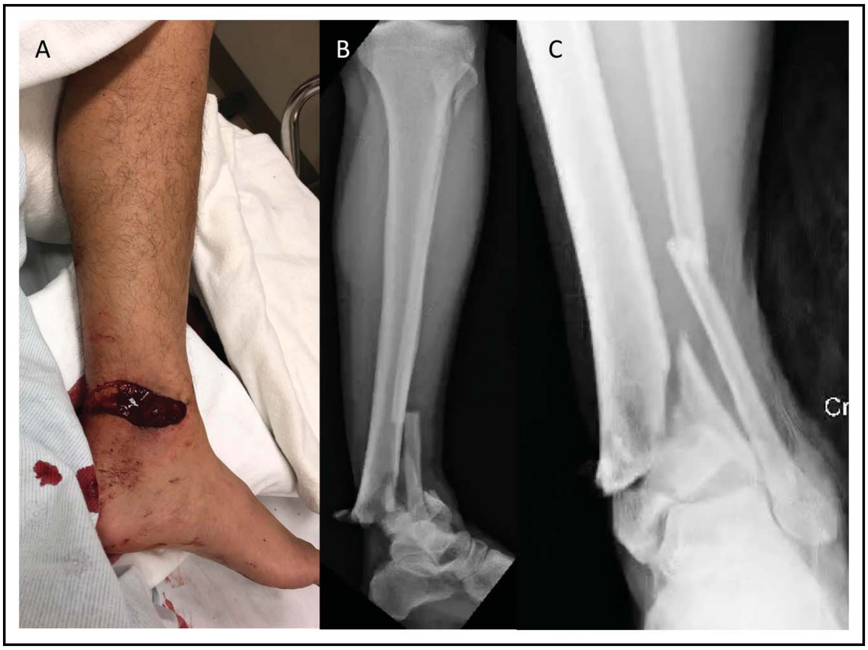
Salvage Versus Amputation

A complete discussion surrounding the decision for salvage versus amputation in these fractures is beyond the scope of this review. However, the surgeon must address two clinical questions. The first is whether salvage is technically feasible. The second is whether salvage is in the patient's best interest. Current indications for lower extremity amputation in the setting of open fracture include sciatic nerve transection and irreparable vascular injury. Relative indications include life-threatening polytrauma in which a prolonged salvage course may threaten the life of the patient (life-over-limb), a dysvascular limb with warm ischemia time >6 hours, a crushed foot with nonreconstructable fracture comminution, notable pre-existing peripheral vascular disease, and rehabilitation concerns.[35] There remains considerable debate surrounding the absence of plantar sensation as a relative indication for amputation. Although several studies have included the absence of plantar sensation in predictive scoring algorithms of lower extremity amputation,[36,37] more recent studies have challenged this hypothesis. For example, in the LEAP study, approximately 55% of those with initial absent or abnormal plantar sensation recovered sensation at 2 years after injury.[38,39]

Soft-tissue Coverage

A basic understanding of soft-tissue coverage options is imperative in planning for initial and definitive management of open distal tibial fractures. The "reconstructive ladder" provides a conceptual framework for soft-tissue reconstruction. When deciding on the most appropriate option for a given wound, the following principles apply: (1) use the simplest option that will achieve optimal function, (2) choose a complex reconstructive method if it will provide the best long-term outcome, and (3) the choice of reconstructive method should be based on the type of donor tissues required (skin, fat, fascia, muscle, tendon, nerve, and bone) and the required function, durability, shape, and contour of those tissues. The so-called "noncritical" portion of the wound includes structures that can heal with primary

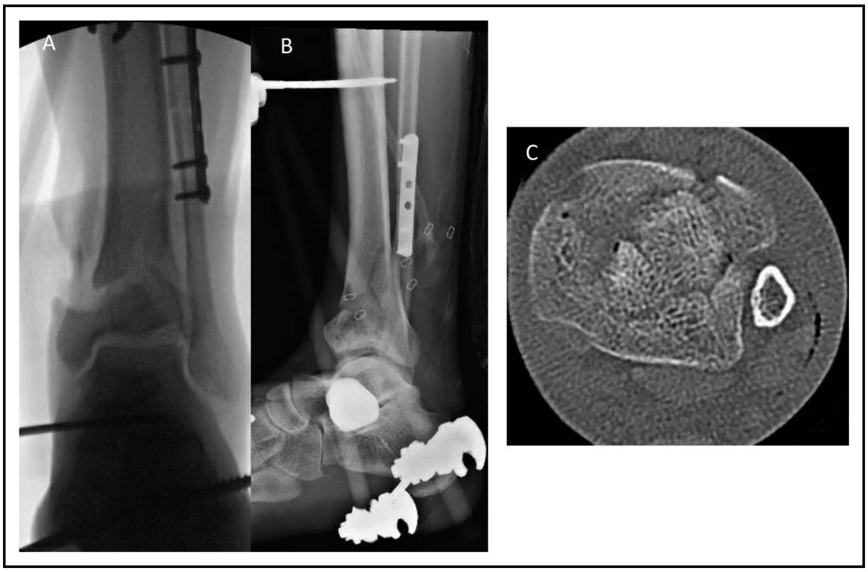
Figure 2



Case 1. **A**, Figure demonstrating the distal tibial fracture with 4 cm transverse wound involving skin, subcutaneous fat, and fascia along the medial aspect of the leg. **B** and **C**, Lateral and AP radiographs demonstrating an intra-articular distal tibial fracture with comminution of both metaphyseal and articular segments (AO/OTA 43.C3 fracture).

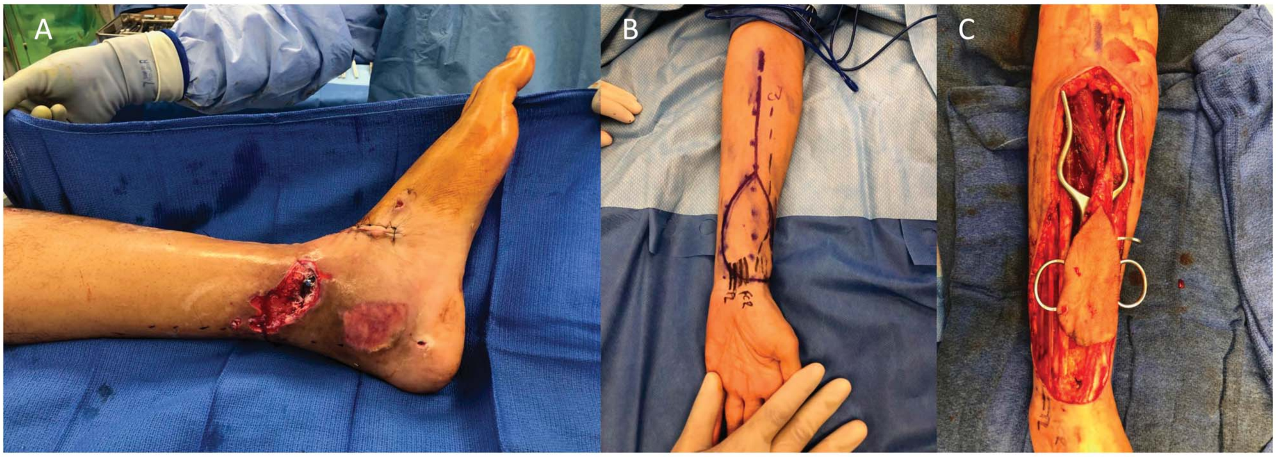
closure, secondary intention, or skin graft—lower rungs on the reconstructive ladder. "Critical" portions of the wound include "white structures" such as nerve, major vessels, bone (without healthy periosteum), and tendon (without healthy peritenon) that require flap coverage. Contemporary studies have reaffirmed Godina principles that aggressive débridement and early coverage lead to better outcomes.[40,41] Although adjuncts such as NPWT have the potential to extend the acceptable window of soft-tissue coverage, it is important to

Figure 3



Case 1. Radiograph demonstrating the limited open reduction and internal fixation of the fibula and biplanar triangular external fixation to restore tibial and fibular length and coaxial reduction of the talus under the tibia (**A** and **B**). A midfoot pin was placed in the medial cuneiform to maintain the ankle in neutral alignment. **C**, A CT scan demonstrating articular comminution and impaction.

Figure 4

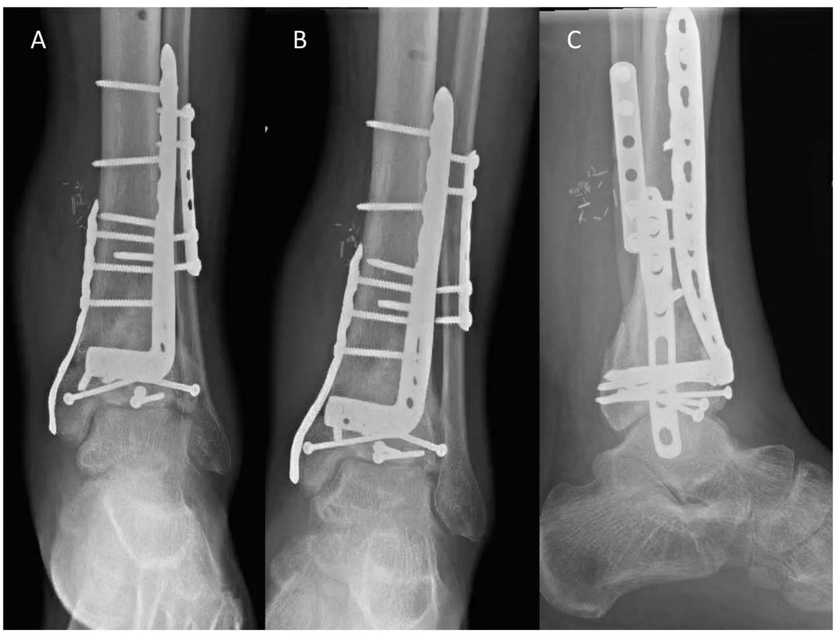


Case 1. **A**, Figure demonstrating the medial wound at the time of definitive fixation demonstrating a 5 × 3 cm loss of skin, subcutaneous fat, and fascia. **B** and **C**, A free fasciocutaneous radial forearm flap was used to cover the defect, with anastomosis to the posterior tibial artery.

remember that early coverage (less than 7 days) should be the goal.[41]

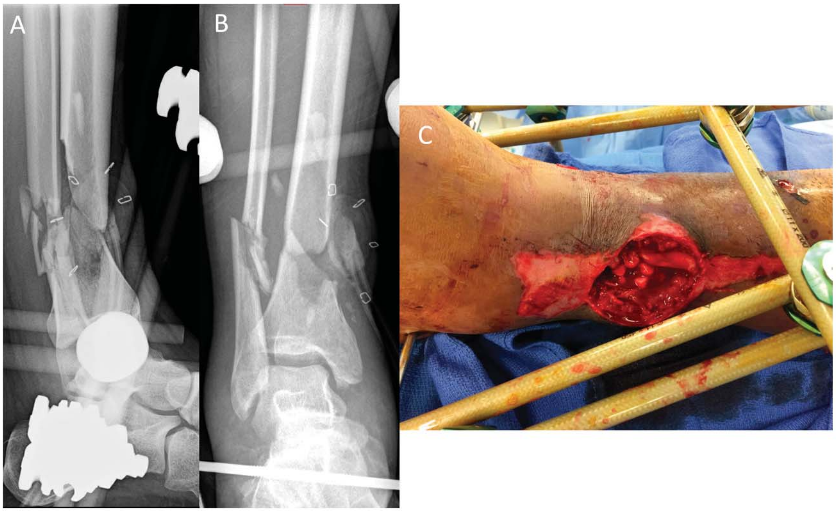
Local flaps for open distal tibial fractures remain uncommon secondary to the paucity of local muscle, minimal skin laxity around the foot and ankle and the size and location of the wound. Of the few local options, a pedicled flap such as a peroneus brevis flap (based on the terminal perforator of the peroneal artery) has the potential to provide sufficient coverage around the ankle.[42] Other options include the reverse sural artery flap (based on the anastomosis between the terminal perforator of the peroneal artery and the superficial sural artery) and the reverse soleus flap (based on distal perforators of the posterior tibial artery). However, because of their relatively small vascular pedicles and the need for almost 180 degrees of rotation to reach

Figure 5



Case 1. Final radiographs (**A**–**C**) demonstrating the soft-tissue shadow of the fasciocutaneous flap, which covers the anteromedial buttress plate.

Figure 6

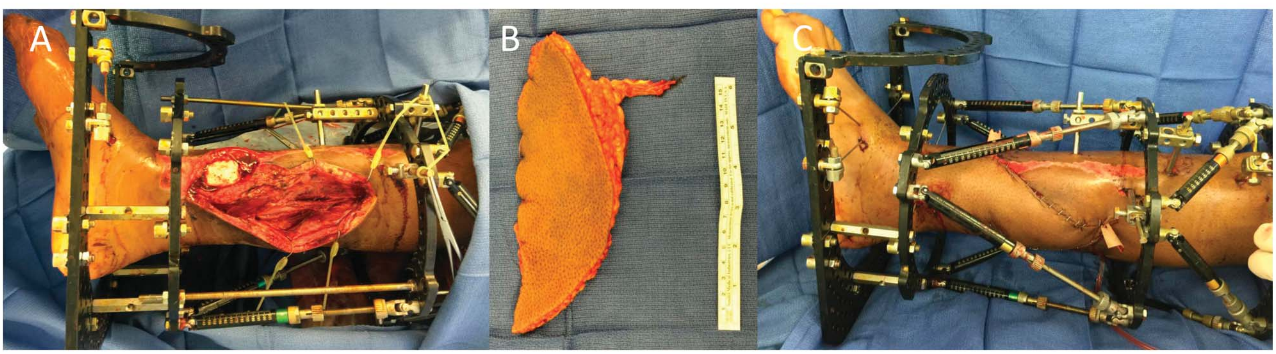


Case 2. **A** and **B**, Radiographs demonstrating the open distal tibial fracture with extensive metaphyseal comminution and bone loss and intra-articular extension (AO/OTA type 43.C2). **C**, Figure demonstrating after débridement and external fixator placement, the elliptical 6 × 4 cm anteromedial wound was temporized with placement of antibiotic beads and negative pressure wound therapy.

the recipient site, these flaps are prone to complications and failure.[35] Consequently, free tissue transfer is often the best option for critical wounds that result from open distal tibial fractures. In these instances, the primary concern of the orthopaedic surgeon must be to preserve all remaining major vessels of the lower extremity. Current free flap failure rates range between 1% and 4% using modern microvascular techniques.[43] Apart from technical failures, the primary determinant in the success or failure of the flap is the status of the recipient vessel. Recipient vessels within the zone of injury or those outside the zone of injury that have been damaged indirectly during the débridement or careless placement of proximal external fixator pins are prone to thrombosis and resultant flap loss.

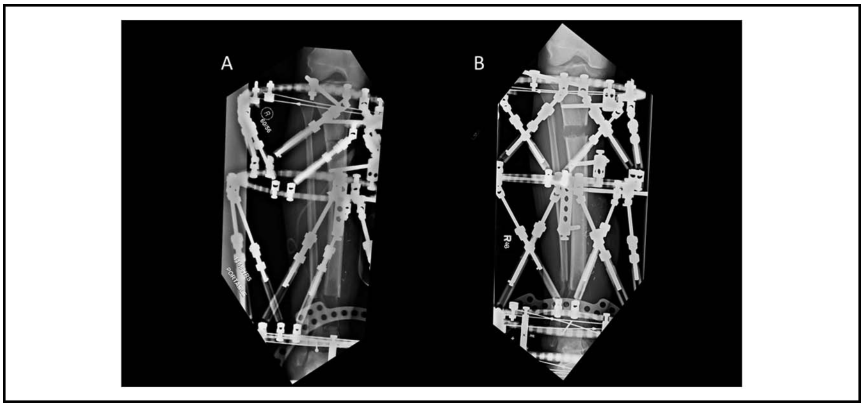
Free flaps used in the distal leg are typically either muscular or fasciocutaneous. Advantages of fasciocutaneous flaps include easier elevation in the setting of secondary bone grafting, improved postoperative monitoring owing to the cutaneous component of the flap, and improved early aesthetic outcome. Muscle flaps, although bulky initially, eventually atrophy and have good long-term aesthetic outcomes and improved conformity over a complex three-dimensional surface (eg, wrapping around the ankle and dorsum of foot). They also have the theoretical benefit of improved

Figure 7



Case 2. **A**, Radiographs demonstrating the postinjury day 9 for limited internal fixation of the articular fracture, application of ringed external fixator, and placement of an antibiotic cement spacer. **B**, The anteromedial soft-tissue defect was managed with an anterolateral thigh fasciocutaneous free-flap. **C**, Construct after free flap.

Figure 8



Case 2. Figure demonstrating the anterolateral thigh flap was later elevated for removal of the antibiotic spacer, followed by proximal corticotomy (**A**) and bone transport (**B**) for management of the metadiaphyseal bone loss.

antibiotic delivery and bone healing because of higher blood flow. Large retrospective studies have shown minimal differences in outcomes between the two flap types.[44-47] For both the soft-tissue surgeon and fracture surgeon, it is important to note that advantages and disadvantages exist to each. The common recipient artery is either the anterior or posterior tibial artery, but selection ultimately depends on the overall quality of the vessel and confirming good in-flow. As mentioned previously, vascular anomalies in the leg have an incidence of 7% to 12% in the general cohort.[10] For example, the incidence of peronea magna (dominant peroneal artery with hypoplastic or aplastic anterior and posterior tibial arteries) is between 0.2% and 8.3% and may limit options for recipient vessels.[48,49] The corresponding vena comitantes and the great saphenous vein commonly provide venous outflow for the flap. The workhorse fasciocutaneous flap is the anterolateral thigh flap which is based on the descending branch of the lateral femoral circumflex artery. The free latissimus dorsi and free gracilis flaps are the most common muscle flaps, especially for larger and more complex wounds (Figures 6–9).

Figure 9

Case 2. Final radiographic and clinical images are shown in **A–E**.

Summary

Advances in our understanding of fracture biology, fracture fixation, temporizing wound management, and microsurgical technique have changed the landscape of both routine management and complex limb salvage in open distal tibial fractures. Relative to other types of open fractures, open distal tibial fractures require special attention. The limited soft-tissue envelope and high degree of fracture complexity make these injuries particularly susceptible to wound complications, infection, and amputation. After initiation of antibiotics and an evaluation of the patient and associated injuries, the primary focus of the on-call orthopaedic surgeon should be on doing an early aggressive debridement, followed by temporizing skeletal stabilization that successfully restores overall length, alignment, and rotation to the limb without limiting options for definitive fixation. Appropriate temporizing wound management with NPWT or local antibiotic bead-pouch should be used if necessary after thorough débridement. A basic understanding of the vascular anatomy and options for soft-tissue management in the distal extremity can help avoid compromising definitive treatment options and ensure the best possible patient outcome.

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