Open Fractures

Definition	Breach in the overlying skin of a fracture.

Epidemiology	Lower limb: 3.3%

Tibia more than 20 folds common than femur. [since tibia is subcutaneous]

Gustillo: 25% each in I, II, IIIa, IIIb [Edinburgh experience]

70% of IIIb, may need flap cover

Upper limb: 3.7% [Hand # common]

System of Gustilo and Anderson

At the time of surgical débridement is useful in guiding treatment and predicting outcomes.

Evaluation

1. **Assessment for polytrauma: ATLS**

a. >50% of open tibial shaft fracture present with other injuries.

b. After initial resuscitation, obtain detailed history of the injury: High Vs Low velocity.

c. Distal circulation check: Look for compartment syndrome.

d. Define the wound [Photograph]; saline clean and dress

e. Tetanus and **prophylactic antibiotic**; Pain medication

f. Splint

e. X ray, CT etc

f. **Debridement** under anaesthesia

g. **Fracture stabilization**

h. **Initial wound management**

i. **Flap cover**

e. Rehabilitation

f. Treatment for nonunion

Vascular Compromise

-Swell muscle

-Severe Pain

-Sensory abnormalities

-Stretch pain

-Capillary refill

-Ankle-brachial index of <0.9 should be evaluated with angiography

Treatment:

-Straighten the leg;

-Debride and fasciotomy

-Vascular repair

FASCIOTOMY

Anterior compartment of the leg:

1. Lateral Fasciotomy incision

2 cm lateral to the anterior border of the tibia

This incision is anterior to the perforating arteries that come from the peroneal artery.

Dissect under the deep fascia to reach peroneal compartment and then decompress

Note: Any vertical incision over fibula: compromises lateral fasciocut. flap

2. Posterior fasciotomy incision

Safe place for fasciotomy avoiding damaging perforating vessels

Medial incision 1-2 cm posterior to the medial border.

This is anterior to Tibial Posterior artery and perforators from PTA goes to posterior to this incision.

Do not undermine skin, otherwise fascio-cutaneous flap cannot be used

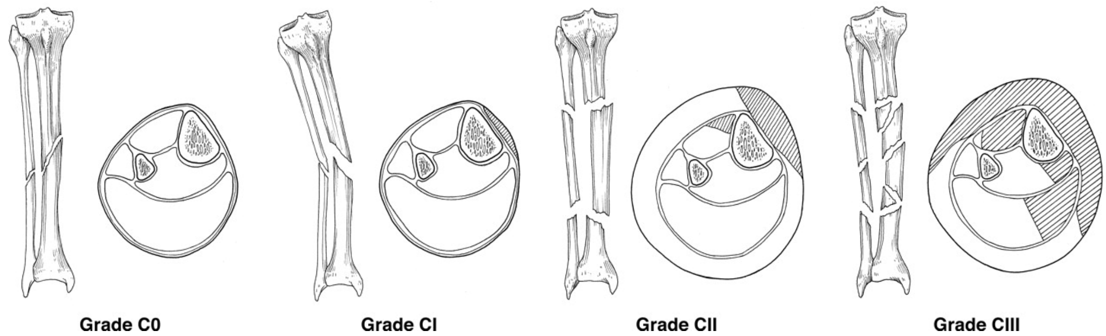
CLASSIFICATION: Gustilo and Anderson

Type I	Wound	Contamination	Soft tissue injury	Bone injury
I	<1 cm	Clean	Minimal	Simple
II	>1cm	Moderate	Moderate	Moderate
IIIA	Usually 10 cm	High	Severe	Periosteum intact
IIIB	“	“	“	Periosteium separated
IIIC			Vascular	

The full extent of the injury to the deep soft tissue and its viability is often underestimated on presentation and may not correlate with the size of the skin defect. The definitive classification of an open fracture should be made in the operating room.

Despite the widespread use of the Gustilo classification, interobserver agreement has been reported to be only 60%.
The Gustilo classification system also has prognostic significance; increasing infection rates and worse outcomes are associated with increasing severity of injury. Infection rates range from zero to 2% for type I fractures, 2% to 10% for type II fractures, and 10% to 50% for type III fractures.

SOFT TISSUE Oestern and Tscherne classification



. Grade O
Minimal soft tissue damage
. indirect injury to limb (torsion)
. simple fracture pattern
.
. Grade1
Superficial abrasion or contusion
mild fracture pattern
.
. Grade 2
Deep abrasion skin or muscle contusion
. severe fracture pattern direct trauma to limb
.
. Grade 3
. Extensive skin contusion or crush injury
. severe damage to underlying muscle compartment syndrome
Subcutaneous avulsion

Wound Culture

Infection of an open tibia fracture is a serious complication that can lead to significant morbidity, delayed union or nonunion, and even amputation. In the absence of antibiotic prophylaxis, infection occurs in approximately 24% of open fractures. Patzakis showed the tibia to be more prone to infection than are other long bones (10.5% [38/363] versus 5.3% [39/741], respectively). This is likely because of the large subcutaneous extent of the tibia, which leads to greater soft-tissue stripping and increased difficulty in obtaining muscular coverage as well as the frequent disruption of significant portions of the vascular supply.

There is no benefit in obtaining preoperative or intraoperative cultures of open tibia fracture wounds. Many subsequent studies have demonstrated that initial wound cultures in the early postfracture setting are ineffective in predicting either infection or the identity of causative organism. In general, wound culture should be obtained only through sterile technique when clinical signs of infection are present.

Host Factors

Many factors contribute to the overall outcome of an open fracture of the tibial shaft. However, diabetes, HIV status, and smoking, in particular, have been associated with delayed union as well as a higher rate and increased severity of infections. Aderinto and Keating13 reported deep infection in two of four open tibial shaft fractures in patients with diabetes. One patient with deep infection required transtibial amputation 4 months after intramedullary nailing. Infection rates of 71% to 100% were reported in two series of open tibia fractures in HIV-positive patients.

ANTIBIOTIC PROPHYLAXIS

Patzakis: demonstrated a significant reduction in infection with administration of cephalothin 2.4% Vs no antibiotics 13.9%.

Coagulase-positive Staphylococcus aureus and β-hemolytic streptococci were the most common pathogens isolated.

Currently, there are insufficient data to conclude that gram-negative prophylaxis is beneficial in the management of open fractures.

Penicillin G is commonly recommended for prophylaxis against clostridial myonecrosis. Nevertheless, the importance of adequate débridement and delayed closure for wounds thought to be at high risk for clostridial myonecrosis (eg, farm injuries, prolonged ischemia) cannot be overemphasized.

Patzakis published the results of a study comparing single-agent ciprofloxacin with a combination of cefamandole and gentamicin. Both regimens provided similar rates of infection prevention in type I and II open fractures. However, for type III open fractures, the infection rate with ciprofloxacin alone was 31%, compared with 7.7% for combined prophylaxis with cefamandole and gentamicin.

TIMING AND DURATION OF PROPHYLAXIS

Antibiotic prophylaxis should be initiated as soon as possible after injury. The benefit of early antibiotic prophylaxis was demonstrated by Patzakis.

Managed with antibiotic prophylaxis >3 hours after injury compared with <3 hours after injury (7.4% versus 4.7%, respectively).

There is evidence to support a short course of first-generation cephalosporin or a similar agent active against gram-positive bacteria as prophylaxis for all types of open tibia fractures. We recommend that the duration of initial wound prophylaxis be limited to a 24- to 72-hour course.

WOUND MANAGEMENT

Timing of Débridement and Irrigation

Most current guidelines recommend that débridement be performed within 6 hours of injury.
Most of the current literature is unable to demonstrate a decreased infection rate for open tibia fractures that are initially débrided within 6 hours of injury compared with those débrided later. We feel that surgical management of low-energy, type I open fractures may be delayed until the following morning; however, although the evidence does not mandate the emergent débridement and irrigation of open tibia fractures within 6 hours of injury, treatment should not be delayed until the end of an elective schedule the following evening. Most surgeons agree that highly contaminated type III open tibia fractures are best treated with urgent surgical débridement and irrigation.

Débridement and Irrigation

Beginning with removal of gross contamination and debris, should be done as soon as possible in the operating room.
A tourniquet should be applied before prepping and draping, but it should not be inflated. Tourniquet use should be minimized.
All necrotic tissue is excised, and the four Cs determines muscle viability: contractility, color, consistency, and capacity to bleed.
Completely free, large cortical bone fragments may be preserved in a sterile fashion to aid in determining length and rotation at the time of fracture stabilization.

In high-energy injuries, it is often difficult to fully determine the viability of all tissues within the zone of injury at the time of initial débridement. Repeat débridement at 48 hour intervals should be done to eliminate devitalized tissue that subsequently develops.

Irrigation is used to supplement systematic and thorough débridement in removing foreign material and decreasing bacterial load. Despite its importance and the frequency with which irrigation is employed, there is a relative paucity of high-quality literature pertaining to the optimal solution, volume, additive, and method of irrigation for open tibia fractures.

Anglen recommended using 3 L of irrigation for type I fracture, 6 L for type II fracture, and 9 L for type III fracture.

Some surgeons use sterile saline alone for irrigation. Antiseptic solutions such as povidone-iodine, Dakin solution, and chlorhexidine disrupt the bacterial cell wall or membrane; these solutions have not been shown conclusively to lower infection rates.

The effect of irrigation pressure has also been evaluated. Evidence indicates that high-pressure pulsatile lavage (HPPL) (nozzle pressure ≥50 psi) is effective in removing bacteria and debris from wounds. However, recent animal studies have suggested that HPPL may be detrimental to bone and soft-tissue structure as well as bone healing and that it may drive bacteria into wounds.

Immediate Primary Wound Closure

Immediate primary closure of an open wound is possible when an adequate amount of viable soft tissue is available to allow closure of an open wound without tension. With modern antibiotic prophylaxis and surgical techniques, immediate primary wound closure is safe and may decrease nosocomial infection by sealing open wounds and providing biologic coverage. DeLong et al35 managed 87 of 119 open fractures with immediate primary wound closure after irrigation and débridement. The authors found no difference in infection or nonunion rates compared with delayed closure.

In the setting of timely antibiotic prophylaxis and thorough débridement and irrigation in a healthy host, we recommend that type I through type IIIA fracture be closed primarily at the time of initial débridement provided that it is possible to achieve a tension-free closure.

In wounds with limited soft-tissue viability, lack of soft-tissue coverage, or severe contamination, other methods of wound coverage should be considered, such as a bead pouch or vacuum-assisted closure.

Local Antibiotics

Polymethylmethacrylate (PMMA) cement is the most commonly used antibiotic delivery vehicle. Typically, 40 g PMMA is mixed with 3.6 g tobramycin, molded into 5- to 10-mm spheres, and strung on suture or wire.

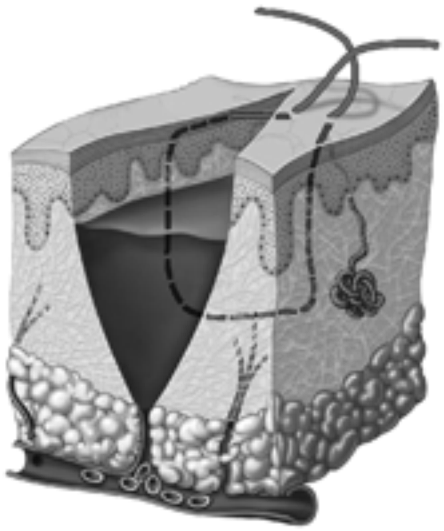
For wounds with inadequate soft-tissue coverage, local antibiotics are often administered through the creation of a bead pouch. The area is débrided and irrigated, the antibiotic-impregnated PMMA beads are placed into an open fracture defect, and the defect is sealed with a semipermeable sterile covering.

More recently, delivery of local antibiotics through bioabsorbable vehicles such as calcium sulfate, demineralized bone matrix, and fibrin clots has shown promise in preventing infection in animal models. These delivery vehicles eliminate the need for removal of PMMA cement and may reduce the number or volume of autografts while providing osteoconductive and/or osteoinductive material to aid in fracture healing.

NEGATIVE-PRESSURE WOUND THERAPY

The Vacuum-Assisted Closure device (VAC) uses continuous subatmospheric pressure (typically, 125 mm Hg) applied through an open-cell foam dressing sealed over a wound to decrease edema, rapidly increase the amount of granulation tissue, and reduce wound size. The popularity of the VAC device has increased tremendously since its introduction, and the device appears to be a versatile tool in

wound management.
Parrett observed a shift in their treatment patterns for open fractures of the lower extremity over a 12-year period. Significantly fewer free flaps were placed in the last 4 years of their series than in the first 4 years (5% versus 20%, respectively).
Dedmond came to similar conclusions when they reported on the use of the VAC device for high-energy open tibial shaft fractures in adults, concluding that the VAC device likely decreases the need for free-tissue transfer.



The Donati-Allgöwer suture pattern. The suture does not exit the epidermis; instead, it anchors vertically in the dermis on the far side of the wound. Increasing tension pulls the far side into opposition with the near side of the wound, but this does not seem to result in kinking or folding of the skin and, thus, does not compromise blood flow. (Adapted with permission from Sagi HC, Papp S, Dipasquale T: The effect of suture pattern and tension on cutaneous blood flow as assessed by the laser Doppler flowmetry in a pig model. J Orthop Trauma 2008;22:171-175.)

DEFINITIVE TREATMENT OF OPEN FRACTURES OF THE TIBIAL DIAPHYSIS
is challenging. The high-energy nature of these fractures, as well as the contamination of the fracture site and devitalization of the soft-tissue envelope, greatly increases the risk of infection, nonunion, and wound complications.

Fracture Stabilization
Early stabilization of open fractures of the tibial shaft is important for controlling pain, protecting the soft tissues from further damage, and providing for early mobilization. Historically, early attempts at stabilization centered on casting and were associated with infection rates >15% and malunion rates of up to 70%.
More recently, improvements in plating techniques, external fixation, and intramedullary (IM) nailing have resulted in better outcomes compared with casting.

Advantages

1. Fracture stability can be helpful in inhibiting bacterial proliferation
2. Access for dressing
3. Allows joint movement
4. Allows for repair and recovery

Site of fracture

Articular fractures should be fixed the screws; or hybrid fixation

Metaphyseal fractures: Minimal invasive plate or nail

Always nail for diaphyseal fractures

Plate: for humerus and forearm

It is not essential to achieve definitive fixation at the first intervention

Blister and definite treatment [Giordano [CORR]

Blister: Aspirate/Deroof and silver sulfadiazine/ leave it alone = no difference

Incision through the blister: serous = heals like a normal incision

Incision directly through blood filled blisters should be avoided

Plate Fixation

Open reduction and internal fixation of open tibial shaft fractures with plates and screws has fallen out of favor because of concerns regarding potential damage to the periosteal blood supply and the high rates of complications, especially infection and exposed hardware. Bach reported severe osteomyelitis in 19% and hardware failure in 12% of Gustilo type II and III open tibia fractures managed with plate osteosynthesis.

Although newer plating techniques, particularly minimally invasive plate osteosynthesis, seem promising because of the capability to limit iatrogenic soft-tissue damage, no study has yet evaluated these newer techniques in the treatment of open fractures of the tibial shaft.

External Fixation

Stability of external fixator

- More proximal - increase stability
- Increase distance between pins
- 6 mm pin strong,
- 3 pins each side is more stable.
- Bar closer to the skin
- Double plane better

Pin track infection control

Predrill,

Use hand for screwing pins,
Release skin around the pin,
Pin track care (IV antibiotics -> Remove pin and drill

External fixation offered two advantages over internal fixation. First, it enabled rapid fracture stabilization. Second, the lack of hardware implantation at the site of the open injury limited further soft-tissue damage.
Overall infection rate of 16.2% with external fixation.
Despite acceptable union rates, high rates of complications have plagued most series, most commonly as the result of pin loosening, pin-tract infection, and malunion.
Pin-tract infection occurs in up to 32% of patients and can lead to chronic osteomyelitis and complicate the conversion to IM nailing. Predrilling should be done to minimize thermal necrosis of cortical bone because it may reduce the incidence of pin loosening and infection.

Intramedullary Nailing
IM nailing is a safe, effective method of stabilization for open tibial shaft fractures.
This technique offers biomechanically superior fixation that maintains length, alignment, and rotation through static interlocking.
It also allows for early weight bearing and adjacent joint motion.
A recent review of the literature on the treatment of open tibia fractures found a union rate of 95% for unreamed nailing (53% Gustilo type III fractures) and 97% for reamed nailing (43% Gustilo type III fractures); however, bone grafting was required in 15.5% of cases, with up to 32% of cases requiring at least one further procedure to achieve union.
An infection rate of 6% to 7% was reported for IM nailing; stratification by Gustilo types was not reported.
Tornetta demonstrated the usefulness of immediate nailing of open tibial shaft fractures. Immediate unreamed IM nailing with meticulous soft-tissue management was found to be safe and effective in 143 open tibial shaft fractures ranging from Gustilo type I through IIIB. A 3% rate of deep infection was reported (1 type I, 2 type II, 1 type IIIB).

Reamed Versus Unreamed Intramedullary Nailing

Reaming is believed to deposit bone graft at the site of fracture. However, it has also been argued that reaming may lead to increased rates of infection and nonunion when it is done in open tibial fractures in which the periosteal blood supply may already be damaged by soft-tissue stripping incurred at the time of injury.
Schemitsch performed a series of experiments using a sheep tibia model and found that although cortical vascularity reconstituted more slowly with reamed nailing, the amount of new bone formed and the strength of the callus were no different between reamed and unreamed nailing.

Prospectivel multicenter, blinded, study enrolled 406 open fractures (108 Gustilo type I, 161 type II, 107 type IIIA, 30 type IIIB) and randomized 210 to reamed IM nailing and 196 to unreamed IM nailing. It was concluded that the optimal nailing technique for open fractures remains uncertain. The current clinical evidence does not support the superiority of reamed or unreamed nailing in the treatment open tibial shaft fractures.

External Fixation Versus Intramedullary Nailing

Bhandari took an indirect approach, using studies comparing unreamed nails with external fixators and studies comparing reamed and unreamed nails. They found a significantly reduced risk of secondary surgery with reamed nailing compared with external fixation. A more recent meta-analysis also found increased rates of malunion and reoperation for external fixation compared with unreamed IM nailing but demonstrated no difference in the rate of union or deep infection.

Secondary Intramedullary Nailing Following External Fixation

Although IM nailing is the preferred treatment of most open tibial shaft fractures, external fixation is still commonly used for temporary stabilization in cases of massive soft-tissue damage or as part of a damage-control protocol. Early studies demonstrated high rates of infection after conversion to IM nailing.
More recent studies, including a prospective randomized trial, have demonstrated deep infection rates of approximately 5% to 6%. These studies typically employed a “safety interval” of casting or bracing between removal of the external fixator and IM nailing to allow granulation of pin sites.
A recent meta-analysis of level III and IV studies identified nine studies (268 patients, 212 open fractures) that reported on planned conversion from external fixation to IM nailing for tibial shaft fractures. Infection was reported in 9% of patients, and union was reported in 90% of fractures.
We advocate conversion to IM nailing as soon as the patient is able to tolerate the procedure and adequate soft-tissue coverage is attained. A safety interval of <10 days should be used in the management of pin-tract infections.

Orthobiologics, Ultrasound, and Electrical Stimulation

The most extensively studied orthobiologics in open tibia fractures are bone morphogenetic proteins (BMPs). BMP-2 (Infuse; Medtronic Sofamor Danek, Memphis, TN) and BMP-7 (OP-1; Stryker, Mahwah, NJ) have been evaluated in randomized clinical trials for their clinical efficacy in the management of open tibia fractures.

Compared with controls, the patients treated with 1.5 mg/mL BMP-2 had a significantly reduced number of secondary interventions. Fewer infections were found in Gustilo type IIIA and IIIB fractures treated with BMP-2.

Currently, only BMP-2 is FDA-approved for use in acute open tibia fractures that have been stabilized with IM nailing after appropriate wound management in skeletally mature individuals.

Limb Salvage and Amputation

Type III open tibia fractures, particularly type IIIB and IIIC injuries, may be associated with such tremendous damage to the bone and surrounding soft-tissue structures that primary or early amputation must be weighed against limb salvage. The decision to amputate or reconstruct the injured limb is complex and involves the consideration of several variables.

When amputation is deemed appropriate in the acute or subacute setting, a second opinion should be documented in the medical record from another orthopaedic surgeon or, preferably, a surgeon from another discipline (eg, vascular, trauma, plastic).

Mangled limb score [Severity Score] Johnssen J Trauma 30:568

Injury	1-4 (Type IIIC)
Ischemia time	1-3(6 hrs)
Shock	0-2
Patients age	0-2

Typical example: Type IIIc + Ischaemia >6 hrs + Hypotensive patient + Age (Old) = Amputation. (PTN absent: consider amputation even in young age). Sometimes primary amputation is desired than complex reconstruction. Needs opinion from 2 surgeons

Numerous objective scoring systems have been proposed to aid in the identification of injuries suitable for limb salvage, such as the mangled extremity severity score; the predictive salvage index; the limb salvage index; and the nerve injury, ischemia, soft tissue, skeletal injury, shock and age of patient score. However, a retrospective study by Bonanni found that these scoring systems could not predict successful limb salvage.

SOFT-TISSUE RECONSTRUCTION

Type IIIB and IIIC tibia fractures often require soft-tissue reconstruction for wound coverage.

Split skin graft

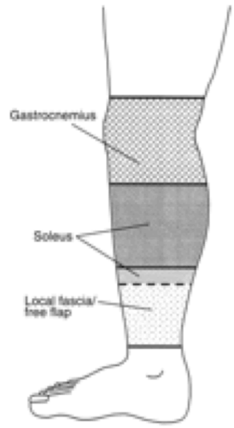
SSG (Particularly for fasciotomy wound)

Meshing the skin grafts in 1:1.5
Mesh graft better than simple sheet graft.
Not applicable: exposed cortical bone, cartilage or tendon

Full thickness graft
Usually for the palm
Less take but better function
Donor: From the forearm or dorsum of the hand
Less contraction [10%] (SSG 50%)

Reconstruction of the soft tissues about the tibia is typically achieved through the use of local rotational flaps, fasciocutaneous flaps, or free-tissue transfer. The location, size, and volume of the defect, as well as the extent of local soft-tissue damage, often determine the reconstruction method. Local rotational flaps may be used in the upper two thirds of the tibia. Typically, a gastrocnemius flap may be rotated into a defect in the superior third of the tibia, whereas a soleus flap can be used for coverage in the middle third of the tibia.

Fasciocutaneous flaps are composites of skin, subcutaneous tissue, and fascia that obtain their blood supply from one or multiple fasciocutaneous perforators. When used as a rotational flap, they are typically random pattern flaps without an axial blood supply. However, local tissue trauma, especially shearing injury, which could tear fasciocutaneous perforators, is a relative contraindication to local fasciocutaneous flaps because the trauma may render these flaps unreliable secondary to a compromised blood supply. Nevertheless, fasciocutaneous flaps are less bulky, may be raised locally or free, and are useful when dead space is minimal, which may be the case in open distal third tibia fractures.



Free-tissue transfer (ie, free flaps) can provide large volumes of undamaged, well-vascularized tissue to cover large defects or three-dimensional wounds with dead space. This technique has been shown to improve tissue oxygenation and decrease the risk of infection. Free muscle flaps covered by a split-thickness skin graft are typically used for open fractures with significant tissue loss.

Recent evidence suggests that outcomes are equivalent between free fasciocutaneous and free muscle flaps for open distal tibia and ankle fracture defects. Thus, choice of flap coverage should depend on the size and three-dimensionality of the defect, available donor vessels, and available donor sites.

Osteocutaneous flaps for segmental defects of the tibia can be used for bony defects of >6 cm in length.

TIMING OF COVERAGE

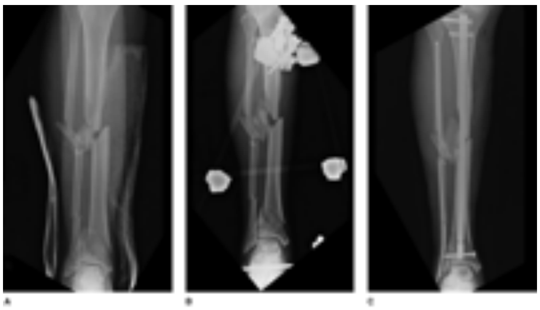
Soft-tissue reconstruction should be performed within 7 to 10 days after injury.

Summary

The definitive treatment of open tibial shaft fractures remains challenging. These fractures should be classified at the time of surgical débridement according the system of Gustilo and Anderson to guide treatment and predict outcome.

Currently, IM fixation is the preferred method of fracture stabilization. External fixation is appropriate in cases of severe contamination and in the setting of damage-control orthopaedics. Conversion to IM nailing should occur within 28 days after injury, with a safety interval employed prior to IM nailing when pin-tract infection is suspected.

Prompt, definitive soft-tissue coverage within 7 days decreases the rate of deep infection and should be a priority. Despite improvements in antibiotic prophylaxis, fracture stabilization, orthobiologics, and plastic surgical techniques, injury severity and patient psychosocial factors have the greatest impact on overall functional outcomes as well as infection and union rates.



AP radiograph demonstrating open segmental tibial shaft fracture in a patient with bilateral lung injury, cervical spine injury, and a forearm fracture involving both bones. B, AP radiograph showing fracture stabilization with external fixation as part of a damage-control protocol. C, AP radiograph obtained after conversion from external fixation to an intramedullary nail with fixation of the fibula to provide added stability to the lateral soft tissue.

SUMMARY

Priorities in surgical management of injury:

- Save life
- Save limb
- Save joints

Restore function

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