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REVIEW ARTICLE

# Management of Open Injuries of the Foot: Current Concepts

[1]Rajeev Vohra, [2]Avtar Singh, [3]Kanwar K Singh, [4]Inderdeep Singh, [5]Navjot Singh, [6]Abhishek Bansal

## ABSTRACT

Open fractures of the foot are rare, and a few surgeons see the whole spectrum of these injuries. When confronted with open injuries of the foot, the decision to salvage the foot needs to be taken after thorough assessment of bony and soft tissue injuries and the associated life-threatening injuries. Foot and ankle surgeon, plastic surgeon, and vascular surgeon must work as a team to provide a pain-free functional and plantigrade foot that fits into a conventional shoe or a brace.

Aggressive debridement and wound management remains the cornerstone of modern surgical treatment. If debridement and wound management can convert a contaminated traumatic wound into a clean surgical wound, which can be adequately covered within 7 to 10 days, then definitive skeletal fixation is advised. In the presence of severe soft tissue and bony injuries, the reconstruction needs to be staged and planned to match the unique personality of the patient and injury.

Amputation can be a positive step toward decreasing the overall morbidity in the presence of severe injury and poor host biology. Despite appropriate treatment, the prognosis of the patient with severe open foot injuries remains guarded.

**Keywords:** Foot, Fractures, Open.

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## INTRODUCTION

Open fractures of the foot are rare and a few surgeons see the whole spectrum of the injuries.[1] When confronted with compound injuries of the foot, a correct judgment is required to decide whether to proceed with an immediate amputation or begin the steps needed for foot salvage. Several graded scores, such as Mangled Extremity Severity Score,[2] Limb Salvage Index,[3] and Predictive Salvage Index[3] have attempted to facilitate this decision. Unfortunately, the clinical usefulness of these scoring systems in predicting amputation has not been validated, and these scores should be cautiously used by a surgeon to decide the fate of the lower extremity.[4] However, certain factors that influence outcome and possible amputation in patients with severe foot and ankle injury (Table 1) need to be considered.[5]

Patients sustaining open fractures of the foot often have concomitant injuries, which need evaluation using advanced trauma life support principles. About 10 to 17% of patients with a severely traumatized limb have associated life-threatening injuries.[6,7] At times in a life-threatening situation, a probably salvageable foot needs to be amputated to save the life.[8] However, the decision to salvage the foot needs to be taken with caution. Protracted limb salvage may demonstrate only technical advances, leaving the patient physically, emotionally, and psychologically in ruin.[9-11] Numerous studies have demonstrated better functional results in severely open foot injuries treated by amputation, particularly when the

[1,3]Senior Consultant, [2]Senior Consultant and Head, [4-6]Senior Resident

[1-6]Department of Orthopaedics, Amandeep Hospital, Amritsar Punjab, India

**Corresponding Author:** Rajeev Vohra, Senior Consultant Department of Orthopaedics, Amandeep Hospital, Amritsar Punjab, India, Phone: +919814536372, e-mail: vohra.r2@rediffmail.com

**Table 1:** Factors that influence outcome and possible amputation in patients with severe foot and ankle injury

| |
|---|
| Duration and severity of limb ischemia |
| Patient age |
| Presence of shock |
| Energy of the injury |
| Degree of contamination (soil) |
| Nerve disruption |
| Open or closed injury (Gustilo open-fracture grading system) |
| Fracture grade, type, level(s) |
| Delay in fracture fixation |
| Elevated compartment pressures |
| Level and type of arterial injury |
| Delay of revascularization |
| Injury severity score/associated injuries |
| Comorbid medical conditions (diabetes mellitus, immune-compromised patients) |
| Transport time, use of pneumatic anti-shock garment |
| Experience of the receiving hospital (trauma center *vs* community hospital) |
| Steroid use |
| Malnutrition |
| Premature wound closure |
| Delayed soft-tissue coverage |
| Operating room time greater than 2 hours |
| Multiple wound exposures outside the operating room |

open fractures were associated with significant soft tissue defects.[12-14] In a recent study that used Sickness Impact Profile as a principal measure, the patients with salvaged feet who required free flaps and/or ankle arthrodesis had significantly worse 2-year outcomes than the patients treated with standard below knee amputation.[15]

Limb salvage is considered when a pain-free, functional, plantigrade foot that fits into a conventional shoe or a brace is expected. When limb salvage is planned in polytrauma patients, the management of concomitant injuries involving head, abdomen, chest, and spine takes priority. It must be kept in mind that polytrauma patients with foot and ankle trauma fare significantly worse than multi-injured patients without foot and ankle injury,[16,17] thus requiring aggressive protocols for open foot and ankle injuries.

Foot salvage requires orderly progression of interventions. In emergency, a thorough analysis of soft tissue and bony injury, including neurovascular status and designation of an initial score, is essential. Numerous scores to classify open fractures include Gustilo and Anderson classification,[18] AO classification,[19] and Orthopedic Trauma Association classification for open fractures.[20] Open fractures are most often classified using the system outlined by Gustilo and Anderson. This scoring system remains the most widely taught and used because it meets the goal of being a simple, guiding treatment, predicting outcome, especially risk for complications.[18] An initial score assigned on presentation needs to be modified after surgical debridement. The wound is irrigated with normal saline to remove gross contamination, and the limb is realigned with a combination of manipulation and traction. A sterile dressing is used to cover the wound and splintage is done before the patient is taken for imaging studies to determine the extent of bony injuries.

Definitive management starts with timely delivery of antibiotics, tetanus prophylaxis, surgical debridement, and copious irrigation. A marked reduction in infection rates with open fractures when cephalothin was administered (2.4%) compared with no antibiotics (13.9%) has been demonstrated.[21,22] Antibiotic delivery should be started as early as possible because a delay greater than 3 hours increases the infection rates.[23] An antibiotic with broad spectrum Gram-positive coverage, such as first-generation cephalosporin should be started, because infections following open fractures are the result of natural skin flora. Multiagent therapy is recommended for type III open fractures, with an aminoglycoside added to the cephalosporin, and anaerobic antibiotic coverage Penicillin G or metronidazole should be added to the initial regimen in barnyard injuries because of predisposition to infection with *Clostridium perfringens*.[24] Antibiotics are generally continued for 24 to 48 hours after the debridement and closure. Antibiotics are restarted with each return to the operating room and continued for an additional 24 to 48 hours after each surgical procedure.[23]

## DEBRIDEMENT AND IRRIGATION

Debridement is the cornerstone of modern surgical treatment.[25] Emergent debridement within 6 hours of injury, suggested by Friedrich,[26] has long been thought necessary to prevent long-term infection. It is not an urgent debridement, but timely thorough debridement following improved resuscitation and early delivery of antibiotics is required. Time of debridement has not been determined to be an independent risk factor for infection in numerous studies.[27-30]

Compartment syndrome of the foot remains to be a true orthopedic emergency and the presence or development of compartment syndrome cannot be ruled out in open fractures and wounds.[31] Untreated compartment syndrome apart from threatening the survival of the foot can cause chronic pain, stiffness, disability, and deformities, such as claw toe, hammer toe, and pes cavus due to ischemic contractures of the muscles.[32] Currently, the three-incision approach is most commonly used for decompressive fasciotomy in the foot.[32-35] This recommendation is based on a nine-compartment model of the foot described by Manoli and Weber.[35] Associated vascular injury requires an immediate surgical intervention. Apart from meticulous clinical examination, Doppler ultrasound screening can have excellent sensitivity and specificity. Multidetector CT angiography may be used as it has good sensitivity and specificity.[36]

The concept of serial debridement, which removes only the tissue that is clearly dead, has largely been replaced by wound excision, which leaves only tissue that is clearly alive. A traditional serial debridement preserves questionably viable tissue in the hope that it is viable and will remain viable, leaving wounds open to allow the desiccation of soft tissues and bone, thus causing infection.[37] When despite the surgeon's best efforts the adequacy of the debridement is uncertain, such as in crush injuries and badly contaminated wounds, a return to the operating room within 24 to 48 hours should be considered. A lack of complete debridement leads to a feedback loop due to release of inflammatory mediators, free radicals, and vasoactive substances, which are detrimental to tissue healing, thus leading to infection and delayed healing.[38]

Adequate debridement usually warrants extension of wounds with incisions made at less than a 45° angle, with full thickness flaps raised to avoid tissue necrosis. All tissues that lack blood supply are excised, starting with skin and proceeding deeper. Large articular pieces necessary for joint stability are usually retained and cleaned with copious amount of saline. Tourniquet may be required to control the bleeding that obscures the surgical field and places vital structures at risk. Furthermore, bleeding from adjacent live tissue may make it appear that devitalized tissue is bleeding and therefore alive. On the contrary, tourniquet can cause tissue hypoxia and hinder the assessment of bleeding from wound margins. After thorough debridement, tourniquet can be released or it can be briefly released and then re-inflated. This staged release of the tourniquet allows viability of all the structures to be examined and wound excision to proceed without torrential bleeding obscuring the surgeon's view.

After surgical debridement, irrigation is performed to prevent infection and promote healing by cleansing the wound of foreign matter, microscopic pathogens, and toxic substances that may inhibit healing. The recommendations for volume of irrigation solution are not evidence based. Available *in vitro* and animal studies indicate that increasing the irrigation volume improves removal of foreign material up to a point, after which there is a plateau effect.[39] One empirical protocol for irrigation is use of 3 liters for Gustilo type I fractures, 6 liters for Gustilo type II fractures, and 9 liters for Gustilo type III fractures.[40] It is important to actively wash all parts of the wound, including cavities and recesses, and not simply flood a particular area with solution.

A wide variety of irrigation solutions, such as water, saline antiseptics, antibiotics, chelating agents, and soaps have been proposed, but normal saline remains to be the most commonly used. Topical antibiotics in the irrigation fluid are toxic to local tissues and do not provide any significant benefit.[40] High-pressure pulsatile lavage can cause additional soft tissue trauma, driving the contaminants deeper into the wound, damaging the superficial neurovascular structure, and causing impaired healing.[41-43] For these reasons, many surgeons prefer low-pressure pulsatile lavage or irrigation with bulb syringe.

After thorough debridement and irrigation, reassessment and re-scoring is done. If it does not seem feasible to provide a functional limb, amputation should be considered as a positive step towards minimizing overall morbidity in severe injuries and not as a failure of treatment. Once the final decision to salvage the foot is taken, it is necessary to stabilize the bony injuries.

## SKELETAL STABILIZATION

Skeletal stabilization is done with an aim of obtaining and maintaining anatomic reduction. The individual hardware recommendations for skeletal stabilization depend on the location of the injury (hindfoot, midfoot, or forefoot). In most circumstances, K-wires or a combination of K-wires and external fixator is used for temporary fixation, but in selective cases stabilization with a fixator may serve as a definitive treatment.[44-47] At times when an immediate definitive fixation is feasible, fixation devices need to be chosen according to the merits of the situation.

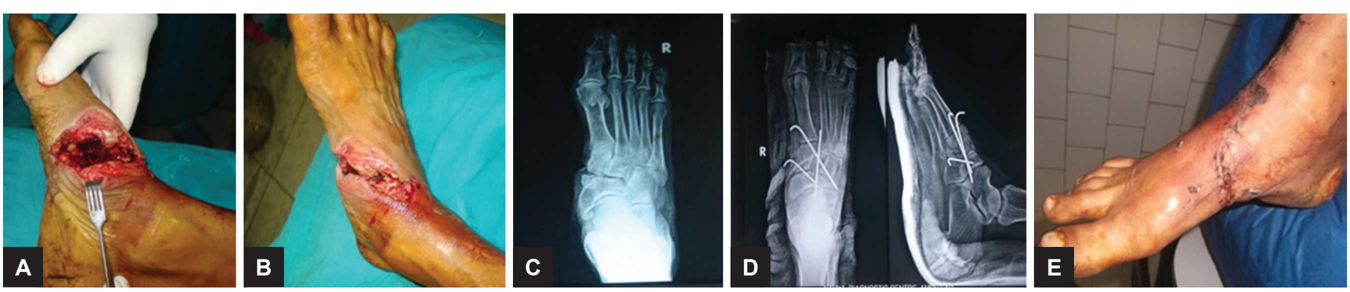
Realignment of bone and joint surfaces decreases abnormal soft tissue motion and irritation and edema, which increase the efficacy of cellular and humoral defenses, thus decreasing the infection rate.[48,49] Skeletal stabilization helps in early mobility and rehabilitation of the patient and thereby improve pulmonary status and decrease incidence of venous congestion and thrombosis.[50-53] Early joint mobility also improves cartilage nutrition and decreases joint stiffness.[54,55]

After skeletal stabilization, compound foot injuries require early durable soft tissue coverage to reduce infection and fibrosis.

## WOUND MANAGEMENT

Current opinion is that primary wound closure is the better option for most wounds, but an early wound closure has its own disadvantages. Early wound closure may lead to retention of non-viable tissue, the potential for infection, and the risk of too tight a closure leading to flap necrosis.[38] Early closure is possible in injuries with minimal or no contamination and limited soft tissue devitalization (Figs 1A to E).

In the past decade, emphasis has been laid on the team approach, incorporating a foot and ankle surgeon, a plastic surgeon, and a vascular surgeon. Although




**Figs 1A to E:** Compound midfoot injury with minimal contamination treated by primary closure after K-wire fixation expeditious wound coverage is associated with lower rates of infection, the timing of coverage is debatable. In his landmark study, Godina[56] advocated coverage within 72 hours of injury to achieve the lowest rates of infection. It is essential to do soft tissue coverage as early as possible, preferably within 7 to 10 days.[38]

Wound dressings are required till the wound is amenable to coverage or secondary closure. Wound dressings should be capable of absorbing exudates, prevent bacterial contamination, avoid further trauma to a wound, and promote healing. Modern dressings, such as some form of hydrogel and alginate or thin covers, such as polymer or silicone have a limited role in acute trauma setting. Antimicrobial dressings are sometimes used to control infection. Hemostatic dressings can be applied directly to hemorrhagic wounds to stop the bleeding immediately. Biological dressings composed of allograft skin, xenograft skin, and collagen matrices are being used more and more in acute trauma. These temporary dressings work in concert with the natural healing process until the wound is prepared to accept definitive coverage.[57]

The advent of negative pressure wound systems has revolutionized our ability to treat soft tissue defects. Currently, these systems are commonly used as a dressing and for promoting healing. Vacuum-assisted closure allows the evacuation of interstitial fluids that accumulate in post-traumatic wounds. These fluids contain inhibitory factors that suppress the formation of fibroblasts, vascular endothelial cells, and keratinocytes, which are crucial for wound healing.[58-60] Negative pressure wound therapy reduces the frequency of dressing changes and prevents wound desiccation that occurs so often if the conventional dressings are neglected.[61] It enhances the wound contraction by secondary intention that can result in spontaneous healing of small defects or allows use of only an autogenous skin graft.[62] In the presence of large wounds, negative pressure wound therapy is a bridge to the definitive soft tissue coverage by flaps.[63,64] Vacuum-assisted closure has been shown to be effective at reducing bacterial counts,[61] so it can be used as an adjunct therapy in cases of failed primary closure or infected cases after debridement.

Bead pouch technique is another method commonly used to control the infection.[65,66] In this technique, antibiotic beads are made by mixing polymethylmethacrylate with an appropriate antibiotic, and the beads are packed into open or dead space and then the wound is either closed or covered with a suitable dressing. The most commonly used antibiotics are tobramycin and vancomycin. The majority of the drug is eluted over the first 24 hours; however, elution may occur in small doses for as long as 90 days.[65,67] Levels which are well above the therapeutic range and have little effect on osteoblast replication can be achieved in wound serum.[68-70]

## SOFT TISSUE RECONSTRUCTION

After wound management, coverage options range from basic to complex and include delayed primary closure, healing by secondary intention, skin grafting, local flap coverage, and distant tissue transfer.[71] The concept of a reconstructive ladder originally used for complex orbitofacial defects was taken over by orthopedic surgeons to reconstruct bone and soft tissue defects.[72-75] According to this rigid ladder (Table 2), the simplest technique should be explored first before proceeding to the next rung of ladder. The problem with this rigid approach is that a wound amenable to a less complex method may not provide the long-term success that can be achieved by a more complex technique. Currently, the use of the procedure that has the best chance of success is recommended.[76]

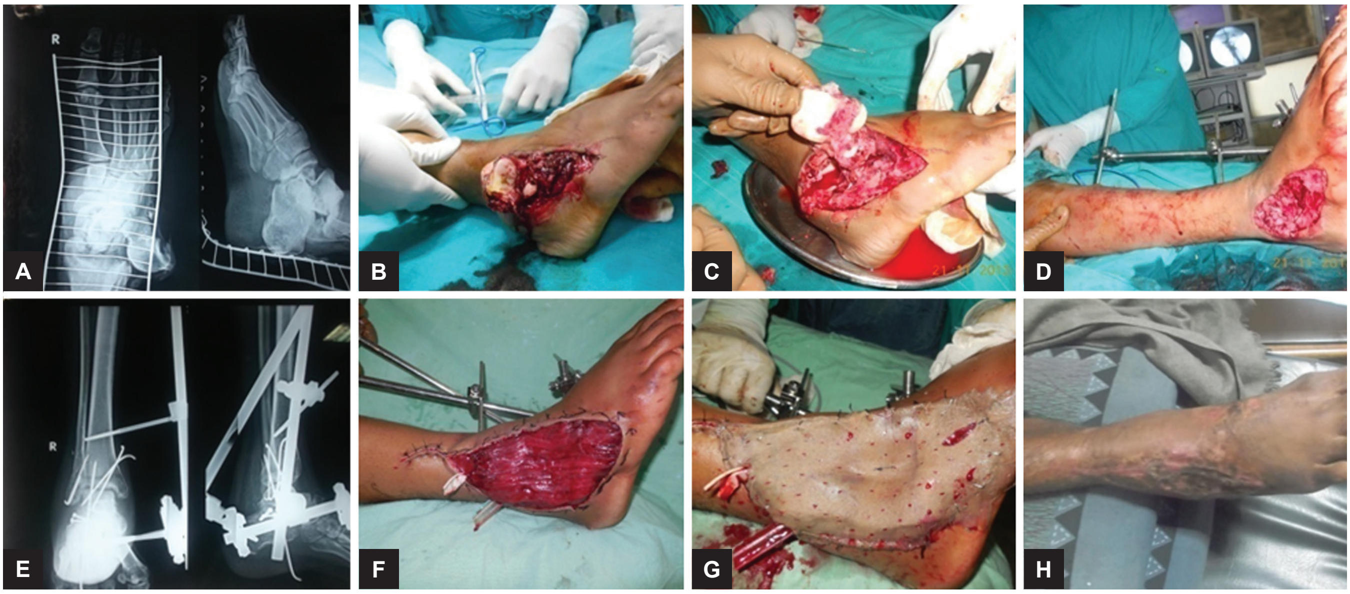
The soft tissue coverage of a particular region of the foot needs to be done keeping in view the specific requirements. Hidalgo and Shaw[77] and other investigators[78] divided the foot into discrete zones according to the requirements of each region. It has been emphasized that any flap selected must meet the functional and esthetic demands of the given zone, with bulk or contour not impeding the use of shoe wear and proper ambulation.[79]

For all practical purposes, there are two types of soft tissue flaps: Muscle and fasciocutaneous flaps, with each having attributes and liabilities.[80,81] Muscle flaps provide increased vascularity, resulting in better oxygen, neutrophil, and antibiotic delivery, and are better at contouring and filling dead space.[38] For large soft tissue defects, mostly free muscle flaps are required. Gracilis (Figs 2A to H) and latissimus dorsi flaps are most commonly used because of their longer pedicles that increase the degree of flexibility in muscle positioning as well as larger diameter vessels that facilitate microvascular anastomosis.[71,76]

The preferences for coverage for each foot and ankle zone have been updated to include perforator flaps, which essentially are fasciocutaneous flaps that do not include muscle.[79,82] The advantages of these flaps include the ability to replace defects of different sizes,

**Table 2:** Reconstructive ladder

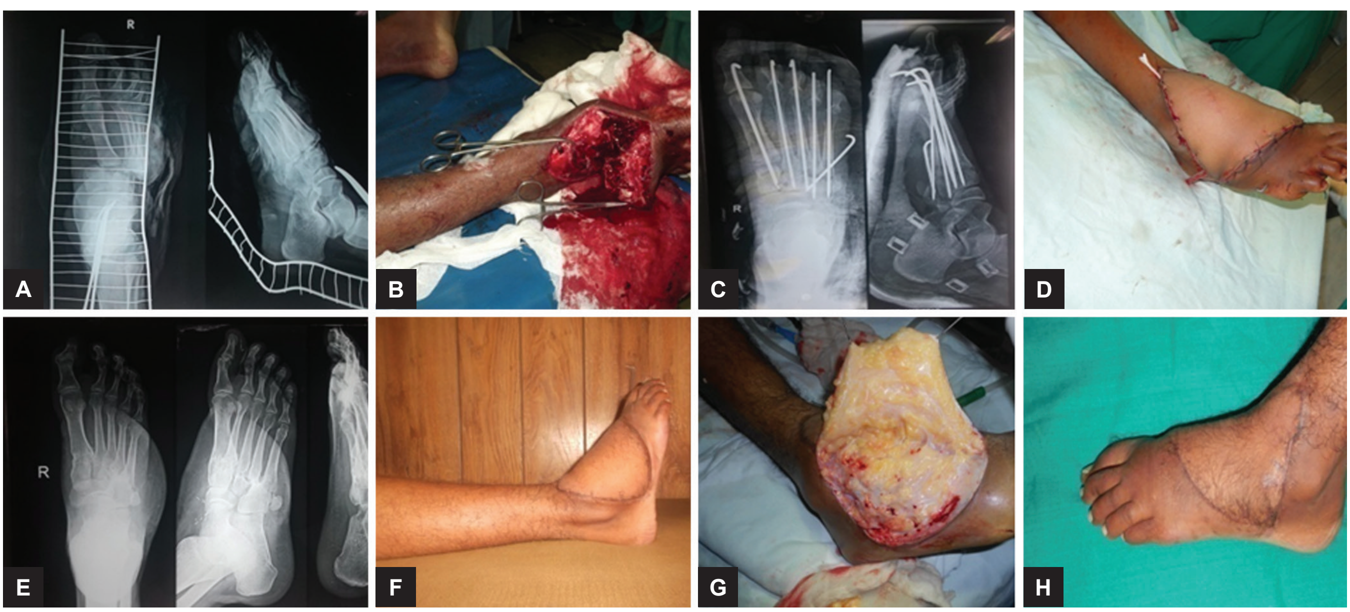
| *Methods* | *Types* |
|---|---|
| Direct closure | Primary, secondary |
| Skin grafts | Split thickness, Full thickness |
| Local and regional flaps | Random, axial |
| Distant pedicle flaps | Random, axial |
| Free flaps | Fasciocutaneous, muscle, musculocutaneous, osteocutaneous |




**Figs 2A to H:** Compound extruded talus with fracture fibula and fracture calcaneus in a 27-year-old male, treated with K-wire fixation and external fixator, and screws for calcaneus and gracilis free flap used for soft tissue coverage

choice of thinness or thickness, avoidance of skin graft, and independence in insetting because they are not constrained by the location of a vascular pedicle.[76] A variety of fasciocutaneous free flaps have been used to cover soft tissue defects of the foot. The most commonly used perforator flaps for the foot include anterolateral thigh flap (Figs 3A to H), medial sural artery flap, and medial circumflex femoral artery perforator (groin) flap.[76] Medial sural artery flap can encompass almost all of the skin of the calf and correspond to the territory of medial gastrocnemius muscle.[76] The donor site is nearby the foot and ankle defect, so any iatrogenic morbidity is limited to the same lower extremity.[83] Some surgeons favor anterolateral thigh flap because of its large surface area, potential large caliber vascular pedicle, and donor site discomfort limited to the same leg.[84] A bulky flap in an obese patient may need thinning for proper shoe fitting.[85]

Other alternatives to cover small soft tissue foot defects include peninsular, propeller, or advancement perforator flaps.[86] Distal-based sural flaps, lateral malleolar flaps, and medial plantar flaps are most common regional flaps used for foot reconstruction (Figs 4A to H). The cross-leg flap commonly used in the past is unacceptable because of long-term immobilization and the need for a staged procedure.[87] It must be re-emphasized that the choice of the soft tissue reconstruction method should




**Figs 3A to H:** Fully healed grade III compound Lisfranc fracture dislocation with healed free antero-lateral thigh flap in an 18-year-old male. The flap required thinning


**Figs 4A to H:** Compound calcaneal fracture with heel pad defect treated by screw fixation and reverse sural flap. Developed infection that subsided after implant removal

be made keeping in view the functional, esthetic, and weight-bearing requirements, and the foot and ankle surgeon, the plastic surgeon, and the vascular surgeon need to work as a team to achieve the goal.

## HINDFOOT INJURIES

Open hindfoot injuries represent a diverse collection of conditions characterized by periarticular fractures of calcaneus and talus and/or joint dislocation with soft tissue disruption. Outcomes with these uncommon injuries are frequently unsatisfactory.[88]

Open injuries of talar neck and body commonly occur in young and middle-aged individuals involved in high-energy trauma. Differentiation between talar body and neck is important, as the neck fractures are extra-articular and do not violate the subtalar joint, but body fractures extend into the ankle joint, subtalar joint, or both.[89]

Open fractures of the talar neck and body are particularly challenging because of the risk of infection, avascular necrosis, and post-traumatic arthritis. After timely debridement and irrigation, if a clean wound bed is present definitive fixation can be done by screws or screw and plate combination provided early soft tissue coverage is possible. Often a second incision is required for confirmation of reduction and application of additional fixation for talar neck fractures.[24] Talar body fractures may need an additional medial malleolar osteotomy for adequate exposure.[88] If an early soft tissue coverage seems doubtful, then a temporary fixation using K-wires with or without an external fixator may be done. There are no studies proving that the ultimate outcome is less satisfactory with staged fixation.[88] In the fractured and dislocated body in open Hawkins III or IV fractures, if attached by medial soft tissues, reduction and fixation should be attempted after thorough debridement and irrigation.[90-92] We tend to preserve talus in such cases (Fig. 2). Less favorable outcomes have been reported in open talar body fractures by Ebraheim et al.[93] Among the six open talar body fractures, five developed osteonecrosis, one had deep infection, six patients had ankle arthritis, and five patients had subtalar arthritis.[93] In another series, six open fractures involving neck or body of talus subsequently needed subtalar arthrodesis due to osteonecrosis and arthritis in two cases and tibio-talo-calcaneal fusion in one case due to osteonecrosis.[94]

Talar extrusions with or without fractures carry a poor prognosis due to complete stripping of the entire blood supply of the talus in most cases. The decision to re-implant or discard the extruded talus is not easy. Due to high rates of infection and avascular necrosis, some initial treatment recommendations included talectomy and arthrodesis.[91,95] However, primary talectomies lead to long-term pain, limb shortening, foot widening, and difficulty with footwear.[96] Sub talar fusions performed in the hope of increasing vascularity to talus may not lead to revascularization and protection against late collapse or arthritis.[97,98] More recent large retrospective case series and a few case reports (Table 3) have shown the rate of avascular necrosis and infection may not be as high as previously thought.[99-104] Lamothe and Buckley[105] recommended reimplanting talus whenever possible, with meticulous attention to the cleaning of the talus, to preserve the normal hind foot shape and mechanics and preservation of bone stock for future reconstructive procedures. The dislocated talus can be reduced and held in place with two smooth pins placed from the inferior

**Table 3:** Complications of talar extrusions

| *Study* | *Number of patients* | *Follow-up* | *Infection* | *AVN* | *Secondary procedure* |
|---|---|---|---|---|---|
| Vesely et al[99] (2015) | 6 | Mean 24.2 months | 2 | | • Subtalar Arthrodesis – 1<br>• Talectomy and Tibiocalcaneal Arthrodesis – 1 |
| Karampinas et al[100] (2014) | 9 | Mean 21.1 months | 2 | 1 | • 2 patients needed arthrodesis |
| Dumbre Patil et al[101] (2014) | 1 | 3 years | – | – | – |
| Breccia et al[102] (2014) | 1 | 18 months | – | – | – |
| Burston et al[103] (2010) | 8 | Average 36 months | 2 | 5 | • Fusion immediate or delayed |
| Smith et al[104] (2006) | 19 | 42 months | 2 | Talar collapse, AVN and/or arthrodesis at 1 year | • 1 primary talectomy<br>• 1 primary below kneerodesis<br>• Amputation<br>• 1 primary tibio-calcaneal arthrodesis<br>• 7 patients required subsequent procedures |

aspect of the calcaneus, through the talus and into the inferior aspect of the tibia, and an external fixation may be added (Fig. 2). We recommend reimplantation of talus after thorough cleaning with pulsatile lavage and soaking in antibiotic solution.

The dislocation between calcaneus and talus involves both subtalar and talocalcaneal joint and is referred to as subtalar or peritalar dislocation. Open injuries make up approximately 20 to 45% of all peritalar dislocations.[106-109] Medial dislocations predominate among closed injuries, but in open injuries lateral dislocations are more common.[106-111] Currently, there is no consensus regarding the treatment of open subtalar dislocations. However, like any other open fracture, irrigation and debridement of the joint and soft tissues is performed urgently.

The majority of reductions performed for open subtalar dislocations are unstable because of severe soft tissue injury or associated intra-articular fractures. Stability can be achieved by smooth pin fixation across the dislocated joint or through fixation of articular fractures. An external fixator has also been advocated to maintain reduction in unstable joints.[112,113] Although most open medial dislocations are amenable to delayed primary closure or skin grafting, lateral dislocations require a myocutaneous free flap in 30% cases.[110] Outcomes following open peritalar injuries are often unsatisfactory due to associated fractures osteochondral injuries, nerve involvement, and tendon injuries.[106,114]

Open fractures of the calcaneus comprise 0.8 to 10% of all calcaneus fractures.[115] They are generally associated with high complications, such as impaired wound healing, deep infection, and osteomyelitis. Folk et al reported wound complications in 72% of open fractures treated operatively.[116] In a retrospective study of 36 open calcaneal fractures, Siebert et al[117] reported more than a 60% complication rate and found that the complication rate was 100% when immediate internal fixation was attempted. Heier et al[118] reported an overall 37% infection rate and a 19% deep infection rate in a series of 43 open calcaneal fractures, out of which 25% were treated with internal fixation and 25% with primary arthrodesis.

Recently, better outcomes have been reported in various series (Table 4).[119-124] In one study, unsatisfactory outcomes were reported in the presence of plantar wound and severe comminution.[120] In another study, factors predictive of a less satisfactory outcome included wound > 5 cm in length, presence of a neurovascular injury, the need for free tissue transfer, and the presence of heel pad avulsion.[125] If the avulsed heel pads do not survive, then flap coverage may be required (Fig. 3). Based on a limited number of studies, with conflicting results in a small number of patients, there is insufficient evidence (grade I recommendation) to support one form of treatment over the other in the management of open calcaneal fractures.[126] In open calcaneal fractures, the severity and location of the soft tissue damage and extent of the comminution and articular damage dictates the treatment.

In low-velocity open fractures with a medial skin split, the so-called "susper lesions" are caused by landing on an everted and externally rotated heel and can be treated by aggressive debridement and early internal fixation through a lateral approach.[127] Thornton et al treated 31 open intra-articular fractures in 29 patients with standard open reduction and internal fixation techniques when the medial wound was < 4 cm and could be closed and remained stable, staying off antibiotics. Percutaneous wire fixation was recommended for wound > 4 cm or unstable wounds.[121] Mehta et al showed good results in 14 patients with grade II or IIIa open calcaneal fractures treated with debridement and temporary percutaneous fixation within 8 hours of presentation and plating through a lateral approach after an average of 18 days.[122]

**Table 4:** Outcomes of open calcaneus fractures

| *Study* | *Number of patients* | *Follow-up* | *Type of wound* | *Treatment methods* | *Complications and outcomes* |
|---|---|---|---|---|---|
| Aldridge et al[119] (2004) | 19 | Average 26.2 months | Medial – 17<br>Posteromedial – 1<br>Posterolateral – 1 | • Staged treatment in 17 patients<br>• Definitive fixation after average of 7 day | • 2 infections requiring amputation<br>• 81.6 average AOFAS ankle hindfoot score |
| Berry et al[120] (2004) | 29 patients (30 fractures) | Average 49 months | Medial – 25<br>Posterior – 2<br>Plantar – 3 | • 10 closed reduction<br>• 2 immediate amputations<br>• 12 K-wire + Ex-fix<br>• 5 staged fixation with definitive fixation through lateral approach<br>• 1 open reduction – bone grafting | • Wound edge necrosis – 1<br>• Heel ulcer – 1<br>• Loss of reduction – 1<br>• Iliac bone infection – 1<br>• 4 subtalar arthrodesis<br>• 1 yriple arthrodesis<br>• Fair to poor AOFAS hindfoot score |
| Thornton et al[121] (2006) | 29 patients (31 fractures) | | Medial – 27<br>Laterally based – 4 | • Medial wound < 4 cm treated by staged IF through lateral approach<br>• Wound > 4 cm and unstable treated by percutaneous K-wires | • 2 laterally based wounds developed infection and required amputation |
| Mehta et al[122] (2010) | 14 | Average 19 months | Medial wound | • Temporary fixation with K-wires and external fixator<br>• Wound management<br>• Definitive fixation with lateral plate after 18 days average | • 1 apical wound necrosis treated by dressing and antibiotics<br>• 1 osteomyelitis needing implant removal and antibiotics |
| Wiersema et al[123] (2011) | 127 | Average 9.1 months | Medial based – 55%<br>Lateral base – 16% | • Emergent Irrigation and debridement<br>• Delayed definitive fixation | • Overall complications 23.5%<br>• 11 superficial wound Infection<br>• 14 deep infection<br>• 6 amputations<br>• 6 culture positive osteomyelitis |
| Beltran and Collinge[124] (2012) | 17 | 12 months | Transversely oriented medial wounds | • Reduction through medial wound percutaneous fixation with screws or pins or both. | • 1 deep infection<br>• 1 wound dehiscence<br>• Secondary procedure<br>• Irrigation and debridement – 2<br>• Subtalar fusion – 3<br>• Triple arthrodesis – 1<br>• Lateral exostectomy – 2<br>• Average AOFAS score – 77 |

Beltran and Collinge treated 17 patients with type II and III open calcaneal fractures with modern soft tissue care, fracture reduction using the medial open fracture wound, and percutaneously placed screw fixation.[124] Aldridge et al[119] and Wiersema et al[123] also recommend staged treatment in open fractures with medial wounds.

In severe open fractures, definitive fracture needs to be delayed to allow adequate soft tissue healing. An immediate reduction of the main fragments is carried out percutaneously and through the existing wound. K-wire fixation of main fragments to the talus (and/or the cuboid) is supplemented by tibiometatarsal external fixation for soft tissue protection. Alternatively, a three-point external fixator may be used to restore the overall geometry of the calcaneus until a definite internal fixation from the lateral becomes feasible.[128] After appropriate wound management, early soft tissue coverage with pedicle or free flaps appears to lower the infection rates and improves functional results after open fractures.[129] At times due to considerable delay in definitive fixation, the injury needs to be managed as calcaneal malunion.

## MIDFOOT INJURIES

Open midfoot injuries are often associated with significant soft issue disruption, making soft tissue stabilization as a primary goal. Treatment of the osseous injury includes maintenance of the length of medial and lateral columns, maintenance of an appropriate relationship between the forefoot and the hindfoot to ensure a plantigrade foot, preservation of motion at the talonavicular joint and the cuboid metatarsal articulation, and stable fixation or primary arthrodesis to maintain anatomical reductions.[130]

Medial column injuries include fractures of navicular, fracture dislocations of talonavicular joint, and fracture dislocations of naviculocuneiform joint. Trauma to the talonavicular joint can result in deleterious changes in pedal motion because talonavicular joint accounts for most hindfoot motion.[131] Every attempt at salvaging this joint should be undertaken before primary arthrodesis is considered.

Comminution of navicular leads to loss of mechanical advantage of the posterior tibial tendon and frank collapse of the medial column.[132] The mainstay of acute navicular crushing injuries is reduction with bridging external fixation to keep the midfoot out of length. If the soft tissue allows, acute treatment entails early open reduction and internal fixation with screws, K-wires, and bridge plating if necessary from the talus to the first metatarsal, which can be removed once consolidation has occurred.[133]

Open injuries of cuboid commonly result from direct crush injury or forced abduction (nutcracker injury). The crushing of cuboid invariably leads to shortening of the lateral column, which causes painful flatfoot deformity.[134] The lateral column can be kept out of length by open reduction or internal fixation and bridge plating if the soft tissue conditions permit. In the presence of gross instability and severe soft tissue injury, early stabilization with an external fixator allows the soft tissues to settle before definitive fixation. Whatever the method chosen, it is essential to preserve the gliding motion of peroneus longus in its groove on the plantar surface of the cuboid.[134,135]

Most cuboid fractures are often associated with other injuries of the foot, and in a series 76% of the cuboid fractures were associated with Lisfranc or Chopart injuries.[136] One study showed that nutcracker cuboid fractures cannot occur in isolation and are stressed due to attention to the associated foot injuries.[137] In massive crush injuries, the length of both medial and lateral columns needs to be maintained. The presence of global comminution may warrant primary fusions.

The intercuneiform joints and the naviculocuneiform joints have little or no essential movements in the normal foot and can be primarily arthrodesed with minimal functional loss,[130] but Chopart joint should be fused as a last resort.

## FOREFOOT INJURIES

Open Lisfranc injuries typically present with significant displacement and instability. Apart from non-anatomic alignment, other factors, such as energy of the injury, cartilage damage, and soft tissue injuries can compromise the final outcome.[138] Stable and satisfactory interim provisional reduction is essential, to prevent further soft tissue damage, and can be achieved by K-wires with or without external fixator. Malunited foot fractures are difficult or impossible to reduce anatomically after soft tissue swelling has resolved and too much time has lapsed.[139] After adequate soft tissue coverage, definitive fixation with screws and/or plates may be required, and at times K-wires may serve as definite fixation (Fig. 4). In a study, 77% spontaneous fusion rate was reported using open fracture protocols, with multiple debridements and multiple K-wire fixation.[140]

Primary fixation may be done provided early soft tissue coverage can be achieved after adequate debridement.[141] A consensus has largely been reached that the fusion of the lateral column should be avoided.[142-144] However, the choice between internal fixation and primary arthrodesis for medial and middle columns is still controversial. A systematic review of 6 studies with 193 patients comparing primary arthrodesis and open reduction and internal fixation found satisfactory and equivalent results in both groups. Mean American Orthopedic Foot and Ankle Society scores of 72.5 and 88.0 were reported for open reduction and internal fixation and primary arthrodesis groups respectively.[145] The injuries with significant cartilage blowout often require primary arthrodesis.

Open fractures of the metatarsals and phalanges and dislocations of the metarsophalangeal joints and interphalangeal can be stabilized with K-wires, placed either longitudinally or in crossed configuration.[44,45] Dorsal or plantar displacement of the metatarsal heads needs to be avoided, to prevent abnormal weight bearing on the foot, which may lead to development of callosities. Crushing injury often leads to a significant loss of motion of the small joints of the toes. Additional dissection contributes to more loss of motion as well as the potential for additional wound problems. A review of 23 open metatarsal fractures in 10 patients found that injuries with minimal soft tissue damage had improved outcomes compared with those with Gustilo-type IIIb injuries.[146]

## CONCLUSION

Prompt decision needs to be taken, whether to proceed with an immediate amputation or begin the steps for foot salvage. When foot salvage is planned, soft tissue management is of paramount importance in the outcome of the patients with foot and ankle trauma. Expeditious wound coverage and early restoration of skeletal anatomy can dramatically decrease complication rates and improve ultimate outcomes.

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