

Open Fractures of the Ankle: Management Options and Factors influencing Outcomes

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ABSTRACT

Open ankle fractures are rare injuries among all the ankle fractures and commonly occur after high-velocity trauma in road traffic accidents resulting in varying amounts of soft-tissue loss, periosteal stripping, microbial contamination, bone loss, and vascular injury. Management of open ankle fractures remains a daunting task due to the complex osseo-ligamentous complex, relatively thin soft-tissue coverage around the joint, propensity for wound infection and complications, and the risk of impaired functional ability. Management in the emergency trauma room includes initial stabilization of the patient, focused history, and detailed clinical evaluation determining the level and type of injury, extent of wound contamination, soft-tissue and/or bone loss, and neurovascular status of the injured limb followed by radiographic evaluation. Early antibiotics administration and wound assessment, irrigation, aseptic dressing, and temporary splintage form the cornerstone of initial orthopedic stabilization of open fractures. There is a general consensus that all open ankle fractures need early debridement and fixation to restore articular congruity and alignment of fracture fragments although the timing of internal/definitive fixation of open ankle fractures is still debatable. Common complications include superficial and deep infections, marginal skin necrosis, compartment syndrome, nonunion/malunion, and secondary osteoarthritis. Timely interventions improve orthopedic outcomes in these patients.

Keywords: Ankle fractures, Debridement, Flap cover, Foot fractures, Open fractures.

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INTRODUCTION

Foot and ankle injuries are among the most common injuries (10%) encountered in orthopedic trauma centers of tertiary hospitals.^{1,2} The majority of these injuries are

severe, often seen in young adult males, and frequently neglected in polytrauma cases. Injuries of the bones constituting the ankle (30.6%) are most common among the foot injuries followed closely by metatarsal (27.9%) and calcaneal fractures (21.4%).^{1,3} Open ankle fractures are rare (3 to 6%) injuries among all the ankle fractures and have also been increasingly seen in the elderly population besides the young trauma patients.⁴ These commonly occur after high-velocity trauma in road traffic accidents, resulting in varying amount of soft-tissue loss, periosteal stripping, microbial contamination, bone loss, and vascular injury. The classification of open ankle fractures based on Gustilo and Anderson⁵ and modified by Gustilo et al⁶ helps in injury description, treatment decisions, and predicting the outcome of injury.

Management of open ankle fractures remains a daunting task for the orthopedic surgeon due to the complex osseo-ligamentous complex, a relatively thin soft-tissue coverage around the joint, which can be easily damaged, propensity for wound infection and complications, and the risk of impaired functional ability in the patient secondary to multiple surgeries. Hence, the goals of management include early wound care and either immediate or staged fixation depending on the wound condition to reduce complications. The purpose of this brief review is to discuss the management options, complications, and factors influencing outcomes of open ankle fractures.

EPIDEMIOLOGY

Foot and ankle injuries have been noted to constitute up to 10% of the total orthopedic trauma cases in tertiary care hospitals from developing countries.¹ A vast majority of these injuries are caused by road traffic accidents followed by falls and industrial accidents and are open fractures. A brief review of studies pertaining to open ankle fractures is provided in Table 1.

MECHANISM OF INJURY AND FACTORS AFFECTING OUTCOMES

Mechanism of open ankle fracture is usually direct impact or crushing injuries as in high-speed motor vehicle accidents and run-over injuries. Sometimes, open fracture can be a result of skin penetration by sharp bone spike leading to the so-called inside-out compounding. This type of fracture is usually low-energy trauma with

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Table 1: A review of studies related to open ankle fractures

Study	Study type	No of patients	Gustillo classification	Treatment protocol	Follow-up	Results
Chummun et al ⁷	Retrospective	68	Divided into three groups: P—patient initially seen and managed by orthoplastic center, S—referral for fixation and management, and R—referral group following complication	Patients from groups “P” and “S” if reconstruction was possible, flap and definitive fixation if not, external fixator and a negative pressure dressing were applied. Combined orthoplastic approach planned next. Group “R” orthoplastic plan for the delayed reconstruction	Mean follow-up; group P: 55.5 weeks; group S: 61.0 weeks; group R: 57.0 weeks	Mean AO scores of groups P, S, and R were 11.5, 12.3, and 9.7 Mean Enneking scores for groups P, S, and R were 63.3, 74.8, and 73.5 (p = 0.16)
Lee and Chen ⁸	Retrospective	47	I: 26; II: 21; III: excluded	Debridement; irrigation, antibiotics, immediate open reduction and fixation, primary wound closure	29 months follow-up: 4	Baird and Jackson ankle score: excellent/good: 90%
Khan et al ⁹	Retrospective	24	Group P—treated primarily by orthoplastic team Group S—referral group	Group P: external fixator, soft-tissue transfer after radical debridement Group S: heterogeneous group, external fixation, plaster application, internal fixation	P: 10.5 months; S: 11.4 months	Enneking score: P: 74.6 S: 70.4 BKA: 2 (one primary treatment); time to union: P: 17 weeks S: 21.6 weeks Functional: excellent 22, good 8, fair 2
Joshi et al ¹⁰	Prospective	30	I: 11; II: 12; IIIA: 5; B: 2	Debridement; irrigation, antibiotics, immediate open reduction and fixation, soft-tissue management according to fracture grade	—	—
Acello et al ¹¹	Retrospective	33	I: 8, II: 7, III: 8	Debridement, irrigation, antibiotics, immediate open reduction and fixation/ amputation, delayed closure	—	—
Tho et al ¹²	Retrospective	15	IIIA: 14 III B: 1	Debridement; irrigation, antibiotics, immediate open reduction and fixation, delayed closure/SSG flap by sec. Intention. 6–12 weeks cast NWB	1–3 years	Range of movement Good: 7 Satisfactory: 6 Poor: 2
Sanders et al ¹³	Retrospective	11	IIIB: 11	Multiple debridement, removal of preexisting implants, antibiotics (intravenous and beads), temporary external fixator or posterior splint. Delayed wound closure with definitive bony stabilization (ankle fusion/ankylosis) including bone graft, in case of flap 4–6 weeks after flap transfer. NWB 3 months	48 months	Mazur ankle fusion score Good: 3, Poor: 5, Failure: 3
Ngcelwane ¹⁴	Retrospective	64	Weber A: 7 B: 26 C: 24 Other: 8. Clean: 42 Contaminated: 22	Debridement; irrigation, antibiotics, immediate open reduction and fixation: 27, 26 K-wires and plaster, 11 plaster only	—	23 had no pain, 21 had pain on weight bearing
Bray et al ¹⁵	Retrospective	31	I: 12, II: 9, III: 10	Group I: debridement, closed reduction, immobilization or delayed open reduction and fixation, delayed closure. Group II: debridement, irrigation, antibiotics, immediate open reduction and fixation, delayed primary closure	I: 90 months, II: 33 months, 1 lost to follow-up	Pain reduction and function in both groups same. Group II: better range of movement. Both groups one infection each
Franklin et al ¹⁶	Retrospective	38	I: 12, II: 14, III: 16	Debridement; irrigation, antibiotics, immediate open reduction and fixation, delayed primary closure	39 months	Function: excellent in 26, fair or poor in 9

BKA: Below-knee amputation; SSG: Split skin graft; NWB: Nonweight bearing



minimal soft-tissue damage and has good prognosis. A number of factors influence the outcome of open ankle fracture, such as the grade, level of contamination, degree of comminution, systemic factors, such as age, nutrition, immunity, systemic diseases, such as diabetes and atherosclerosis, drug and alcohol abuse, timing and quality of fracture reduction and fixation, soft-tissue handling, and wound coverage. The only variables under surgeon's control are fracture reduction and fixation, soft-tissue handling and wound coverage which are discussed in detail below. The majority of other factors are not modifiable; hence, improvements in wound management and fixation of fracture are key areas of future research in this field.

MANAGEMENT

Although the treatment plan for each injury needs to be individualized, the ultimate goals of open ankle fracture management are to save the life and limb of the patient as well as prevent functional disability. Management of open ankle fractures includes the following:

Primary Care

Management of open ankle fractures in the emergency trauma room includes stabilization of the patient including maintenance of airway, breathing, and circulation followed by a focused history about the mode of injury, detailed clinical evaluation determining the level and type of injury, extent of wound contamination, soft-tissue and/or bone loss, and neurovascular status of the injured limb.

Orthopaedic Stabilization

Early antibiotics administration and wound assessment, irrigation, aseptic dressing, and temporary splintage need to be done once initial stabilization has been taken care of. Radiographic evaluation of the ankle joint in two orthogonal planes should be done to evaluate the extent of bony injury. Difficult positioning of the limb during radiography due to pain and open wound may give sub-optimal imaging results and hamper optimal treatment decisions. Any additional imaging, such as computed tomography scans for better evaluation of fracture and planning may be conducted once the injured limb has been splinted.

Early antibiotic therapy, even in cases where surgical debridement has been delayed for more than 6 hours, significantly reduces the rate of infections.¹⁷ The type, dose, and duration of antibiotics are controversial. The organisms causing wound infection depend on the environment of trauma and individual's own skin flora.^{18,19} The most common organisms isolated from open ankle

fracture wounds have been gram-positive followed by gram-negative, anaerobic, and gas-forming organisms.²⁰ Hence, a broader spectrum prophylactic antibiotic, such as first-generation cephalosporin is recommended for open fractures. Additional use of one aminoglycoside is recommended in type III open fractures.^{21,22} In the postoperative period, there are no added benefits of continuing antibiotic therapy beyond 24 to 48 hours in prevention of surgical site infection, and prolonged antibiotic use may cause resistance and poor response to antimicrobial agents.^{23,24}

The goal of wound irrigation is to remove contamination, and loose, necrotic, and nonviable tissues in turn decrease the bacterial contamination. However, the question about "how much irrigation?" still remains unanswered. The traditional orthopedic teaching emphasizes "Dilution is the solution to pollution" and "If a little is good, more must be better." Gustilo and Anderson⁵ recommended irrigation with 10 L of normal saline to decrease the infection rate in open fractures. A minimum of 9 L of normal saline is recommended for type III wounds. Irrigation of open fracture wounds with antibiotic solution has not been seen to be advantageous over the use of a nonsterile soap solution in randomized controlled trials, and it may increase the risk of wound-healing problems.^{25,26} It was thought that use of antiseptic solution with normal saline like iodine, chlorhexidine, and hydrogen peroxides will further reduce the bacterial load, as they have bactericidal properties. However, the use of antiseptic solution has not been supported in current literature because of its toxic effect on the injured tissue. In a recent, large, multicentric (41 clinical centers), randomized study funded by the Canadian Institutes of Health Research, the authors investigated the effects of castile soap *vs* normal saline irrigation delivered by means of high, low, or very low irrigation pressure.²⁷ A total of 2,551 patients with open fracture of an extremity were randomly assigned to undergo irrigation with one of three irrigation pressures (high pressure >20 psi, low pressure 5 to 10 psi, or very low pressure 1 to 2 psi) and one of two irrigation solutions (castile soap or normal saline). The authors concluded that the rates of reoperation were higher in the soap group than in the saline group and were similar regardless of the irrigation pressure, a finding that indicates that very low pressure is an acceptable, low-cost alternative for the irrigation of open fractures.²⁷

Wound Debridement

The seminal work by Gustilo and Anderson⁵ showed that debridement of the open fracture wound and irrigation need to be urgent. However, recent literature advocates an "early" in place of "urgent" debridement.²⁸

Recent studies have reported that adequate debridement done beyond the proverbial “golden period” of 6 hours under the cover of optimal antibiotic therapy can give comparable results to that done within golden hours of trauma.^{17,29,30} Adequacy of debridement around the ankle joint is difficult to judge due to paucity of thick and long muscles and, hence, depends on the surrounding soft tissues and skin.

Fixation

Why to Fix?

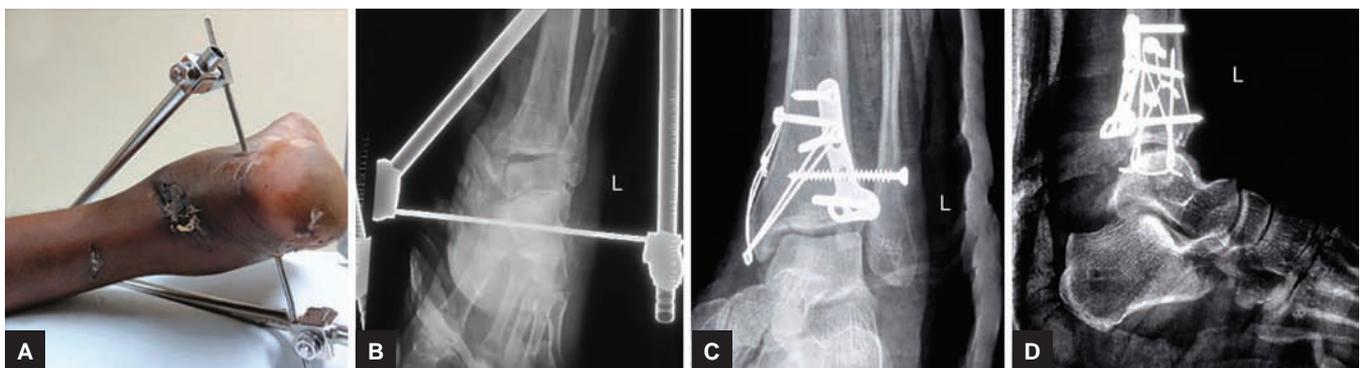
The benefits of fixation of open ankle fractures include protection of soft tissues from additional injury by fracture fragments, improvement of wound care, early tissue healing, promotion of early mobilization and rehabilitation, and possibly reduction of wound infections. A good fixation is imperative to achieve good orthopedic outcomes because of the large amount of bone loss and articular cartilage damage, inability to achieve articular reduction, postoperative loss of anatomical reduction, and deep infections. All these problems portend poor outcomes and painful secondary osteoarthritis.^{16,31} Fixation also helps in restoration of limb length and alignment, which further improves the vascular and lymphatic flow. It also helps in identification of extent of the wound and potential need for soft-tissue coverage. Additionally, restoring the normal anatomy of the limb with fixation not only helps in understanding the fracture pattern, but also helps to eliminate dead space, which can act as a source of hematoma and bacterial growth. Anatomic articular reduction can generally be accomplished early, if the articular surface is easily accessed through the open fracture wound. If the articular injury is simple and the wound is clean, immediate fixation should be considered. Early fixation improves wound access. Application of large bulky splints and dressings makes wound inspection and access difficult. Fracture stabilization with either internal or external fixation devices also allows wound

care with ease. In essence, fracture stability improves overall patient care.

When to Fix: Early vs Delayed?

There is a general consensus that all open ankle fractures need to be debrided as soon as possible and fixed to restore articular congruity and alignment of fracture fragments, but there is a lack of high-quality literature/consensus on the timing of internal/definitive fixation of open ankle fractures (Fig. 1). Gustilo and Anderson⁵ advised avoidance of primary internal fixation for open fractures due to an imminent risk of implant infection. Instead, the authors advocated temporary fixation with traction pins incorporated into the plaster cast. For many years, no specific guidelines were advocated for internal fixation of foot and ankle fractures. Franklin et al¹⁶ reported 38 open ankle fractures treated with immediate debridement and internal fixation. The authors did not encounter any infection, and this was attributed to the bony stabilization itself, which protected the soft-tissue envelope, thereby decreasing the risk of infection.¹⁶ Bray et al¹⁵ performed a comparative study of 31 open ankle fractures, of which 16 were treated with immediate internal fixation and 15 with delayed internal fixation. One infection was reported in each group; however, the authors noted a trend for decreased hospital stay for the patients treated with immediate internal fixation.¹⁵

Use of internal fixation in the management of open fractures needs great caution because of the high inherent risk of infection in such injuries. Recent literature now provides support for early definitive fixation of all open ankle fractures³² supplemented by good supportive care, timely antibiotics, wound management, negative pressure dressings, and early wound cover with local or free flaps.⁷ In general, it is safe to proceed with immediate internal fixation for simple fracture patterns in clean wound environments.^{1,3} Most type I and II open fractures can be managed with immediate open reduction and internal fixation as long as the wound is clean and immediate/



Figs 1A to D: (A) Clinical photograph of the patient showing open wound after debridement and suturing. Spanning external fixator was applied to keep the fracture aligned till the ankle is ready for internal fixation; (B) Anteroposterior; (C and D) lateral views of left ankle radiographs after final fixation



Figs 2A to C: (A) Clinical photograph of the patient showing poor skin condition. Anteroposterior views of left ankle radiographs showing the fracture before; (B) and after (C) external fixator

early closure is feasible. Immediate open reduction and internal fixation of type III articular fractures of the ankle have been tried in select cases.^{15,16} With the emergence and access to external fixation, the philosophy of damage control in orthopedic trauma has gained popularity. The principles of damage control may also be applied to high-grade open fractures, in polytrauma, and hemodynamically unstable patients. In such cases, debridement followed by splinting or placement of an ankle-spanning external fixator can be considered³³ (Fig. 2).

Wound Coverage

The question of primary *vs* delayed closure/coverage of open ankle fractures has long afflicted the orthopaedic fraternity without conclusive evidence for or against either modalities. Treatment of 532 open extremity fracture patients with flap coverage within 72 hours, between 72 hours and 3 months, or after 3 months showed that early (<72 hours) flap coverage was associated with significantly lesser repeat procedures, fewer postoperative infections, shorter time to bony union, and shorter hospital stays.³⁴ In 84 type IIIB or IIIC open tibia fractures, an aggressive protocol of debridement outside of the zone of injury, immediate fracture stabilization, and immediate flap coverage (<24 hours), early (<72 hours), or late (>72 hours), showed better outcomes and lower infection rates with immediate and early flap coverage groups.³⁵ Benson et al³⁶ compared primary closure (44 wounds) *vs* delayed closure (38 wounds) at an average of 6 days and did not find any statistically significant difference in the infection rates. Superficial infection developed in three primary closure patients. Deep infection developed in two patients with delayed closure. A study of 119 open fracture wounds managed with various wound coverage techniques showed no statistically significant difference in infection rates between immediate and delayed closure

groups.³⁷ Role of interim wound management in open grade IIIB fractures while permanent coverage is awaited seems critical. A retrospective study of 229 open tibial fractures comparing 166 wounds with negative pressure wound therapy during the time until permanent coverage could be done and 63 wounds with conventional dressings found that the negative pressure wound therapy group had 80% reduced risk of deep infection over the conventional dressing group.³⁸ Similarly, Liu et al³⁹ retrospectively reviewed 105 free flap reconstructions for lower extremity trauma. The authors concluded that the patients who received soft-tissue coverage within 3 days had significantly fewer operations and flap revisions, preflap infections, deep infections, osteomyelitis, and shorter hospital stays compared with those patients who were reconstructed beyond 7 days.³⁹

In conclusion, astute clinical judgment is necessary for primary closure of open ankle fracture wounds. Primarily, type I and II, and few of type IIIA wounds may be amenable to primary closure/coverage. Wounds that are grossly contaminated warrant thorough and sometimes multiple debridement before permanent coverage is undertaken. In fragile areas where skin and soft tissue are marginal, such as foot and ankle region, leaving a wound completely open leads to skin retraction and makes a coverage procedure difficult. So, it is prudent to approximate the skin edges at the first surgery itself, which facilitates subsequent coverage procedures. For wounds not amenable to immediate closure because of contamination or severe degree of skin and soft-tissue loss, several options exist and delayed primary closure can be attempted by 5th day. Management of the wound by conventional dressing, packing, bead pouch techniques, and negative pressure wound therapy (Fig. 3) should be undertaken until definitive closure/coverage can be achieved. This strategy allows for repeat irrigation and debridement of

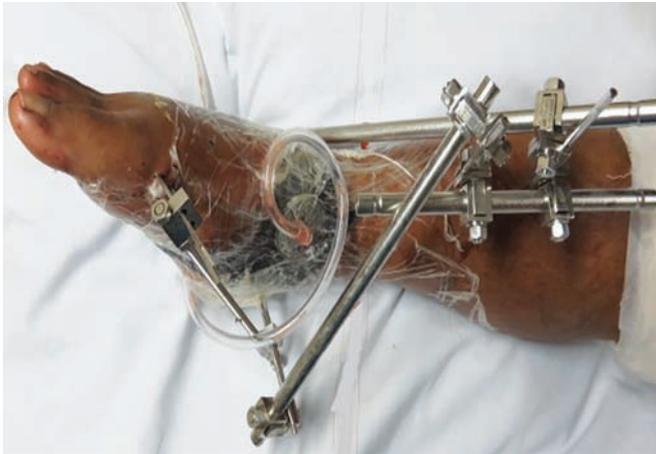


Fig. 3: Clinical photograph of the patient showing negative pressure dressing



Fig. 4: Right ankle showing wound breakdown in a case of open ankle fracture after staged final fixation

the wound and minimizes the risk of infections. When immediate closure or delayed primary closure is not possible because of skin and soft-tissue loss, the wound must be covered by alternative strategies. In wounds with a healthy vascularized bed with adequate granulation tissue, skin grafts provide the best option for coverage. If there is profound soft tissue defect and exposed bone, flap coverage becomes necessary. Flap coverage is generally not done at the time of initial debridement, but works well in converting an open injury into a closed one making it amenable for subsequent procedures.

Management of Complications

Minor Wound Complications

In recent meta-analyses of 498 open ankle fractures, skin necrosis was noted in 14% patients.³² Superficial infections and marginal skin necrosis require regular dressings and commonly settle with short course of oral antibiotics.

Deep Infections

These are infections where pathogenic microorganisms invade the ankle joint or the soft tissues (Fig. 4). The reported incidence is variable from 6 to 40%.^{11,12,40} A recent meta-analysis concluded that deep infections occur in 8% of open fracture patients.³² Besides the need for repeated surgeries and hospitalizations, deep infections may portend poor outcomes secondary to delayed or nonunion and ankle arthrodesis.⁴¹ Such infections may need multiple surgical debridement and prolonged course of intravenous followed by oral antibiotics. Preventive steps include preservation of soft tissues surrounding the fracture site by lavage, thorough debridement, and early administration of antibiotics.¹⁰ Internal fixation should only be done when there is adequate soft tissue to cover the implant; external fixation may be considered otherwise.⁴¹

Compartment Syndrome

Acute compartment syndrome is a painful condition that develops after tissue ischemia and swelling in a tight compartment after injury or fixation of fracture. It needs immediate intervention to relieve symptoms and may lead to permanent tissue damage, fibrosis, contractures, and loss of function. Development of acute compartment syndrome of foot following open or close ankle fractures is a distinct possibility in all trauma patients and has been sparingly described in literature.^{42,43} Use of tourniquet should be minimized, and if used, should be kept for less than an hour.

Non/Malunion

Nonunion is more common in open ankle fractures because of multiple reasons, such as loss of soft-tissue cover, damage to the blood supply to fractured bone ends, and deep infection. If not healed by conventional repeat fixation and bone grafting, it leads to secondary osteoarthritis and may need ankle arthrodesis.⁴⁴

Secondary Osteoarthritis

Secondary osteoarthritis or posttraumatic osteoarthritis is a well-known entity after open as well as close ankle fractures irrespective of the type of management (conservative or operative).⁴⁴ Risk factors include lateral talar displacement, injury to ankle ligaments, and fibular malunion with shortening and valgus deformity.⁴⁵ Severely affected patients may even need ankle arthrodesis to control the pain.

In conclusion, open ankle fractures are rare injuries among all the ankle fractures and commonly occur after high-velocity trauma in road traffic accidents, resulting in varying amounts of soft-tissue loss, periosteal stripping, microbial contamination, bone loss, and vascular injury. Management of open ankle fractures remains a

daunting task due to the complex osseo-ligamentous complex, relatively thin soft-tissue coverage around the joint, propensity for wound infection and complications, and the risk of impaired functional ability. Early antibiotics administration and wound assessment, irrigation, aseptic dressing, and temporary splintage form the cornerstone of initial orthopedic stabilization of open fractures. There is a general consensus that all open ankle fractures need early debridement and fixation to restore articular congruity and alignment of fracture fragments although the timing of internal/definitive fixation of open ankle fractures is still debatable. Timely interventions improve orthopedic outcomes in these patients.

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