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# Definitive treatment of open tibia fractures

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## Summary

In the last years significant progress has been achieved in the management of open tibial fractures and improving outcomes. However, these open fractures continue to remain one of the most challenging injuries to manage in orthopedic traumatology. This is primarily due to the relative paucity of soft tissues around the tibia. This kind of injury often requires combined treatment by both orthopedic and plastic surgeons. Stable fixation and early wound coverage are the basic principles in treatment of open fractures. The fix and flap technique suggests that open reduction and internal fixation (ORIF) and soft-tissue free-flap coverage should be performed during the same surgical operation within 72 hours, because the time interval between injury and definitive treatment seems to be a more important risk factor for infection. However, in most hospitals this interval is impossible to respect, demanding a close collaboration between orthopedic and plastic surgeon. The purpose of this manuscript is to provide a realistic and practical algorithm to treat these complex injuries, even in those hospitals in which a well-defined Ortho-Plastic team is not present.

**Key words:** open tibia fractures, management open fractures, exposed fractures

## Introduction

Open fractures of the tibia are the most frequent exposed fractures of long bones with an annual incidence of 3.4 cases per 100,000 inhabitants; in 80% of cases, the medial and distal third of tibia are involved [1]. These fractures are mostly the result of high energy traumas, and represent a significant challenge for the orthopedic surgeon because in most cases they have extensive bone/soft tissue loss and lesions of neurovascular structures. The optimal treatment of these lesions is still debated, and the recent advent of the ortho-plastic surgical team has considerably changed management [2-4]. The aim of this paper is to define, schematically, what cases can be managed by definitive orthopedic fixation and when provisional fixation and plastic surgeon intervention is necessary considering the recent literature.

## Classification of open fractures

Multiple classification systems have been prosed for open fractures [5,6]. However, these injuries are usually classified according to the system developed by Gustilo and Anderson and subsequently modified by Gustilo et al. [7,8]. This system, which was specifically intended for tibial fractures, has found widespread acceptance for most long-bone open fractures; it considers the energy of the trauma and the degree of soft-tissue injury and contamination, which have prognostic implications [7,8] (Tab. I).

Although this classification system is associated with low interobserver reliability [9,10] (average 60%), it remains the preferred system to categorize open fractures,

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**Table I. Gustillo classification system.**

| Type | Gustillo classification | Infection rates |
|---|---|---|
| I | Low energy, exposure less than 1 cm, low degrees of contamination and comminution | 0-2% |
| II | Exposure of between 1 cm and 10 cm, contamination, soft-tissue injury and moderate comminution | 2-5% |
| III | Exposure greater than 10 cm, high degree of soft-tissue injury and contamination | |
| IIIA | Primary coverage is possible | 5-10% |
| IIIB | Primary coverage is not possible | 10-50% |
| IIIC | Arterial injury requiring repair | 25-50% |

since the fracture type correlates well with the risk of infection and other complications; for example, rates of infection have been reported to be 0 to 2% for type A and up to 25 to 50% for type III C (Tab. I). Furthermore, the surgeon must be aware that the risk of infections is also associated with patient characteristics and comorbidities (i.e., age > 80 years old, nicotine use, diabetes, malignant disease, pulmonary insufficiency etc.); indeed, in patients with three or more compromising factors, infection increase significantly [11].

## Treatment

Schematically, we can divide treatments in two groups considering Gustillo classification. The first group includes types I, II, and IIIA Gustillo fractures, and the second group types IIIB and IIIC fractures. This division considers the different problems that should be addressed. In latter group, primary soft tissue coverage is not possible and bone loss is usually present; in these cases, treatment is more complex requiring the intervention of plastic surgeons and more than one orthopedic procedure.

## Gustillo type I, II, IIIa tibia fractures (adequate soft tissue coverage, no bone loss)

In these types of injuries, the immediate definitive fixation of the tibia is applicable in many cases, facilitating healing and functional recovery [12,13].Differently, temporary fixation must be considered in three different situations: 1) for high-energy trauma with suffering of soft tissue especially in Gustillo type III A; 2) severely traumatized patients with associated vital lesions limiting surgical aggression; 3) in a precarious health context with limited technical means or massive casualty situations. These situations are part of damage orthopedics control (DCO) [14,15]. The ideal definitive osteosynthesis device (plate, intramedullary nail, external fixator circular or monolateral etc.) depends on: 1) degree of soft tissue damage (not always correlated with bone coverage; 2) fracture site (articular-extrarticular); 3) patients general conditions; 4) mechanism of injury; 5) surgeon's experience.

### Shaft fracture

Nowadays intramedullary nailing is the preferred technique. During the late 1980s, several studies demonstrated favorable outcomes with definitive external fixation [16]. However, more recently, some studies have shown intra-medullary nailing to be preferable to external fixation. This technique is associated with a lower prevalence of malalignment, fewer subsequent procedures, and a lower rate of infection compared to external fixation [17,18]. Nailing also has advantages over external fixation: better clinical tolerance, easy access to soft tissue, better control of axes and rotation, and early mobilization and recovery [19]. Studies comparing reamed and un-reamed nailing in patients with an open tibial fracture have proved inconclusive [20]. Differently, the use of antibiotic coated nails is recommended since a lower incidence of infection has been observed [21]. Nailing after removal of the external fixator can be performed in 1 or 2 stages. The two stage procedure has the theoretical advantage of healing the skin at the sites of the fiches, but primary nailing without waiting also appears to be a safe procedure. The two stage procedure is recommended when the temporary fixator is maintained for more 28 days. An interval of 9 days seems to be recommended in secondary internal nailing [22].

### Articular fracture

Operative treatments include internal and external fixation modalities. One stage ORIF is possible in case of a minimal level of soft tissue involvement. However, staged surgical reconstruction remains the standard treatment protocol at most trauma centers. This includes application of a temporary spanning external fixator for approximately one to three weeks, followed by open reduction and internal fixation once the surrounding soft tissues are amendable [23]. A temporary spanning external fixator permits a CT scan to better characterize the articular surface fracture patterns. Advanced imaging can help guide the surgeon on the incisional approach and the selection and positioning of the implants [24]. Studies have demonstrated a lower incidence of wound complications and deep infections with this staged protocol compared to early open reduction internal fixation [25].

### External fixation as definitive treatment

Several techniques of external fixation are described in the literature. These include simple ankle spanning or ankle sparing bridging frames, circular frames, and hybrid frames [26]. In ankle spanning systems, the functional outcome was also reported to be significantly poorer in comparison to ankle sparing systems [27].

The use of external fixators in definitive management is no longer a mainstay in management. A meta-analysis comparing the management of open tibial fractures showed no difference in the rate of nonunion and infection with external fixation compared with internal fixation methods. However, there were significant differences in the rates of malunion and need for further surgery, supporting the use of internal fixation as definitive treatment [28,29]. Nowadays, external fixation methods for a primary and definitive treatment are mainly indicated in tibial pilon fractures, where the risk for severe complications due to a poor soft tissue envelope, grade III open fractures or severe comorbidities of the patients is very high [30].

Definitive external fixation methods can also be combined with limited open reduction and internal fixation (ORIF) or minimally invasive techniques, for example percutaneous K- wire or lag-screw constructs, to better reduce the articular surface [31].

### Open reduction and internal fixation

Nowadays a staged protocol is the main choice for ORIF in the treatment of exposed articular tibial fractures. The main goals are anatomical reconstruction of the articular surface and the restoration of the correct rotational alignment to achieve best functional results [23]. The state of the soft tissue dictates timing of surgery. "Wrinkling of the skin" seems to be the best indicator for operability, which in most cases will occur 10-14-20 days after the trauma. Multiple studies have compared the outcomes of ORIF and external fixation. Outcomes seem to be similar in terms of early complications, but a significantly higher rate of superficial infection mostly due to pin tract infections has been noted. However, the rate of deep infections did not vary significantly in ORIF and external fixation. The rate of mal union was significantly higher with external fixation than with ORIF, which is most likely due to the limited possibility of anatomical reduction with external fixation. Additionally, the functional outcome seems to be worse with external fixation than with ORIF, which was also due to the reduced possibility of anatomical reconstruction of the articular surface [32-34].

## Gustillo type IIIb IIIc tibia fractures (primary coverage not possible, bone loss)

These fractures are potentially devastating injuries; they often present with extensive soft-tissue damage, bone loss and vascular injuries. A delay in wound coverage is associated with an increased rate of infection and surgical failure [35]. For proper management of these traumas, a multidisciplinary approach (orthopedic/plastic/vascular) is necessary [36]. In recent years, the British Orthopaedic Association (BOA) and British Association of Plastic, Reconstructive and Aesthetic surgeons (BAPRAs) have introduced protocols on how one may approach open traumatic injuries [36]. BOA/BAPRAs guidance recommends that wound cover be established within 72 hours of injury and not delayed beyond seven days. The two procedures, orthopedic fixation and plastic coverage, the so-called 'fix and flap approach', should be performed at the same theatre setting [36]. This approach is considered optimal in managing lower extremity injuries and limiting complications associated with delayed repair[36]. Indeed, according to Gopal et al., the "fix and flap" technique has shown that early wound closure and early fixation reduces infection rates and promotes fracture healing and early restoration of function [37,38]. Unfortunately, although the most recent studies showed that the Ortho-Plastic approach is better than the orthopedic one alone, many hospitals do not have the benefit of a combined emergency team. Furthermore, the cooperation between orthopedic and plastic surgeons is not always easy, even when both teams are available in the same center, due to the lack of communication and the absence of standard guidelines for the management of complex wounds; for these reasons, 7 days is a more realistic time than 72 hours [39]. Indeed, it is recommended that definitive soft tissue reconstruction be undertaken within the first 7 days after the injury, and if this window of opportunity for conversion is missed, definitive management with modern multiplanar/circular external fixators should be considered [36-39].

Negative pressure wound therapy (NPWT) allows maintaining a clean and well vascularized wound floor while waiting for the plastic surgeon intervention [40]. Furthermore, its use after debridement may allow for flap repair beyond 72 hours without an increase in the infection rate and may reduce flap necrosis [40].

In tibial shaft fractures, without bone loss, nailing is preferred technique [17-19]. Differently, circular external fixation is a better choice if a significant amount of bone loss is present and the articular surface is involved[17-19].

Recently, Tetsworth et al. proposed a new classification system of bone defects [41]. These can be broadly classified into one of three categories and then further classified into one of three subcategories for a total of nine possible combinations. In keeping with the existing alpha numeric scheme, categories are appended the suffix "D" followed by a number (1-3), and the three subcategories are then designated the letters A-C (Tab. II).

A critical bone defect (D3) should be always treated; there are many techniques available to treat these complex injuries, i.e., autologous bone grafting, induced membrane technique, distraction osteogenesis, acute limb shortening and lengthening, and vascularized fibular allograft. The most appropriate treatment must be carefully thought out on a case-by-case basis. Distraction osteogenesis via the use of an external fixator

**Table II. Classification of bone defects, see text for details.**

| |
|---|
| D1 – Incomplete defect<br>(*Involve a maximum of three out of four cortices*) |
| A: < 25% cortical bone loss |
| B: 25 to < 75% cortical bone loss |
| C: > 75 to 99% cortical bone loss |
| D2 – Subcritical/minor defect (< 2 cm)<br>*(Are distinguished by the shape of the fracture ends)* |
| A: 2 oblique ends |
| B: 1 oblique and 1 transverse end |
| C: 2 transverse ends, ie, segmental defect |
| D3 – Segmental/critical size defect (≥ 2 cm) |
| A: 2 to < 4 cm |
| B: 4 to < 8 cm |
| C: ≥ 8 cm |

appears to be the most popular technique. The main advantages of distraction osteogenesis are its reliability, ability to bear weight during reconstruction, and, most importantly, the absence of limits with regards to size of the defect that can be reconstructed. The disadvantages, however, are the length of time required to achieve consolidation (an average of 10-12 months for a defect of 10 cm in size) and the resultant physical and psychological burden on the patient with prolonged transports [42].

In a recent long-term study looking at the Ilizarov technique the rate of union was 91.2% with, however, a high re-operation rate [42].

The Ganga Hospital Open Injury Score (GHOIS) was proposed in 2004 and is designed to specifically address the outcome in IIIb injuries of the tibia without a vascular deficit [43]. It evaluates the severity of injury to the three components of the limb-skin, bone and musculotendinous structures separately on a grade from 0 to 5. Seven comorbid factors which influence the treatment, and the outcome are included in the score with two points each (Tab. III).

The total score was shown to predict salvage when the value was 14 or less; amputation when the score was 17 and more. A gray zone of 15 and 16 is provided where decision making should be made on a case-to-case basis.

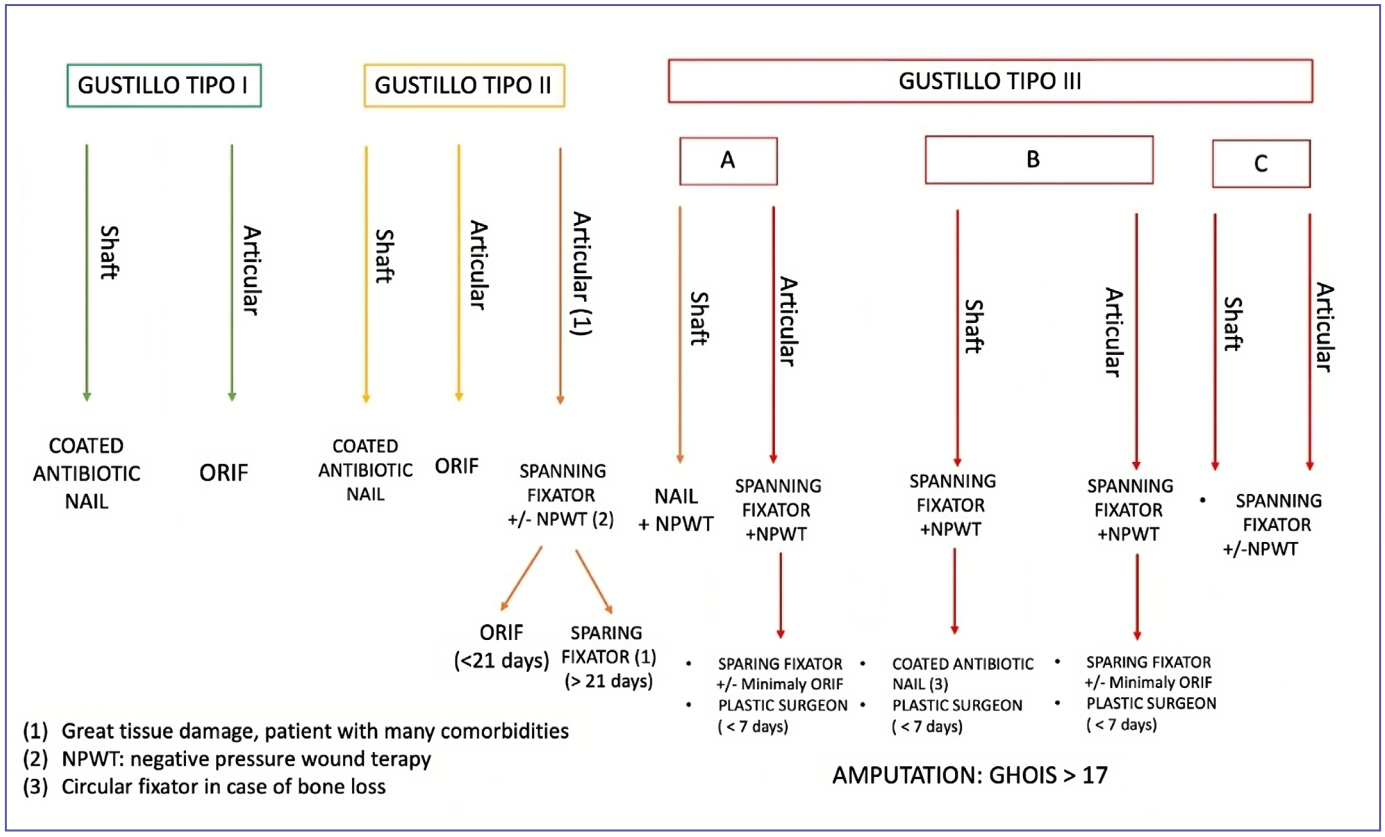


**Figure 1. Practical algorithm to treat open tibia fractures.**

**Table III. Parameters of Ganga Hospital severity score, see the text.**

| Parameter | | Score |
|---|---|---|
| **Skin losses** | No loss<br>Some loss/degloved<br>(+2 to above if over bone) Extensive loss/exposed bone | 1<br>2<br>5 |
| **Soft tissue injury** | No injury<br>Repairable<br>Irreparable<br>Loss of < 2 compartments Loss of > 2 compartments | 1<br>2<br>3<br>4<br>5 |
| **Bony injury** | Fracture, no bone loss<br>Joint involvement<br>Bone loss: < 4 cm<br>> 4 cm | 1-2<br>3<br>4<br>5 |
| **Additional risk factors** | Age > 65<br>Contamination<br>Chronic illness<br>Systemic injury<br>Other trauma | +2 for each |

## Conclusions

Open fractures represent a challenge to even the most experienced orthopedic surgeons. The available evidence supports the current trend towards earlier coverage and closure of open fracture wounds. The early closure of open fractures grades I, II, IIIa is recommended with the obvious exception of wounds that are grossly contaminated. Grades IIIb and IIIc injuries should be managed by specialist teams and the wound should be closed at the earliest possible time. Figure 1 shows a realistic and schematic algorithm to treat these complex injuries even in those hospitals in which a well-defined Ortho-Plastic team is not present.

*Conflict of interest stament*

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All authors conceived, designed and wrote the manuscript.

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