

# Infections in primary intramedullary nailing of open tibial fractures: a review article

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**Abstract. – OBJECTIVE:** Open fractures are insidious and life-threatening injuries. They frequently involve the leg. Our aim is to evaluate the efficacy of primary intramedullary nailing as a definitive treatment of open tibial fractures, compared to other fixation tools in terms of deep infections, healing fracture time and bony repair.

**PATIENTS AND METHODS:** We reviewed the available literature concerning treatment and management of open tibial fractures.

**RESULTS:** Primary intramedullary nailing is similar to delayed intramedullary nailing after external fixation in terms of union, malunion and nonunion rate.

Furthermore, primary intramedullary nailing is superior compared to all other fixation tools, in terms of development of deep infections, provided that a good debridement of soft tissue, lavage of the fracture site and adequate antibiotic prophylaxis should be performed before nailing.

**CONCLUSIONS:** Primary intramedullary nailing should be considered for the definitive treatment of open tibial fractures, providing many advantages in terms of rehabilitation, time of hospitalization and costs.

## Key Words

Open tibial fractures, Primary intramedullary nailing, Deep infections, Nonunion, Malunion, Soft-tissue debridement.

## Introduction

An open fracture is a circumstance in which disruption of the skin and underlying soft tissues result in a communication between the fracture and the outside environment. The incidence of open fractures of long bones is 11.5 per 100 000 persons per year, involving more often young males after a high-energy trauma. Almost 40% of this pattern of fractures occur in the lower limb and especially at the tibial diaphysis because of the thinness of the cutaneous layer and the underlying soft tissues around this region<sup>1</sup>.

According to the Gustilo and Anderson classification, open fractures are classified into three

types based on the size of the open wound, the degree of its contamination and the extent of the related soft-tissue injury (Table I).

It is recommendable to ascertain the type of the open fractures room after surgical exploration, and not only in the emergency room.

Brumback and Jones recently found the Gustilo and Anderson classification system to be associated with a low interobserver agreement, amounting to 60% on average, which the authors characterized as “moderate to poor”<sup>2,3</sup>.

Despite these limitations, the Gustilo and Anderson classification remains the preferred system for categorizing open fractures since each fracture type is a good predictor of the correlated risk of infection and other complications.

The management of open fractures still remains one of the greatest challenges to orthopedic trauma surgeons. An open fracture involves indeed significant damages to soft tissues, such as skin, muscles and neurovascular structures, which represent additional variables that the surgeon must take into account. Due to the high number of factors at play, open fractures are much more prone to deep infections and complications such as malunion, nonunion, etc. with relevant consequences for the patient in terms of restore of the limb function, increase of time of hospitalization and health care costs.

After adequate initial stabilization of the patient, the open fracture should be treated in the operating room as soon as possible, preferably within six hours of the injury. The origin of the so-called “six-hour rule” is unclear, however.

The neurovascular status of the limb should be evaluated, such as arterial pulses, capillary refill, color of the limb, motor and sensory function if possible.

In the operating room, a prompt lavage and debridement of the wound should be performed. Irrigation is crucial in preventing infection after open fracture in order to decrease bacterial load and to remove foreign bodies. We found little data on exactly how much volume should be used in

**Table I.** Classification system of Gustilo Anderson.

| Fracture type | Definition   | Historical Infection Rates (%) |
|---------------|--|--------------------------------|
| I             | Wound <1 cm; minimal contamination, comminution, and soft-tissue damage      | 0-2                            |
| II            | Wound >1 cm; moderate soft-tissue damage, minimal periosteal stripping       | 2-5                            |
| IIIA          | Severe soft-tissue damage and substantial contamination; coverage adequate   | 5-10                           |
| IIIB          | Severe soft-tissue damage and substantial contamination; coverage inadequate | 10-50                          |
| IIIC          | Arterial injury requiring repair   | 25-50                          |

the lavage of open fracture wounds, but evidence recommends a quantity ranging from 3 liters for type I to 9 liters for type III of sterile saline solution. Additives such as povidone-iodine, chlorhexidine or antibiotics may be included<sup>4</sup>.

The role of prophylactic antibiotic therapy in the initial management of open fractures is well-established. The risk of infection and the type of the offending microorganisms depend on the severity of soft tissue damage. Currently, there is controversy with regard to the specific antibiotic agent(s) to be given after open fractures. However, the systemic administration of a second-generation cephalosporin for 48 to 72 hours seems to be adequate prophylaxis for type-I open fractures and should be associated with an aminoglycoside (usually gentamicin) for type II and III<sup>5</sup>. Most agree that penicillin or ampicillin should be added when there is the risk of anaerobic infection (for example, following farm injuries). The optimal duration of antibiotic therapy is less clear, but evidence shows that a three-day duration is adequate and that a longer period could increase the risk of antimicrobial resistance<sup>6</sup>.

Restoration of alignment of the limb should take priority in the initial management since marked angulation and displacement or prominent bone fragments could exert excessive pressure on soft tissues or neurovascular structures.

Fixation of open fractures has several beneficial effects, including protection of soft tissues from additional injury by fracture fragments, improvement of wound care and tissue-healing, early mobilization and rehabilitation, and reduction of the risk of the infection incidence.

A better understanding of the underlying pathology and recent advances in fracture fixation have considerably changed our view on treatment for open fractures.

In the literature, many options in the treatment of open tibial fractures are assessed. The aim of this study is to review the features of the surgical techniques used in the treatment of open tibial

fractures, focusing on the evaluation of the efficacy of primary intramedullary nailing as a definitive treatment of open tibial fractures, compared to other fixation tools in terms of deep infections, healing fracture time and bony repair.

## Patients and methods

A literature review using the PubMed/Medline database was performed in order to identify scientific publications relevant to the treatment and management of open tibial fractures. Open tibial fractures, primary intramedullary nailing, deep infections, nonunion, malunion, soft-tissue debridement were used in our search in order to retrieve the relevant publications.

## Results

External fixators, plates and screws, and reamed or unreamed locking nails are available tools for open fractures stabilization. External fixation is a well-established method for the temporary stabilization of long bone open fractures in a polytrauma, especially in cases of severe soft tissue damage and wound contamination. Historically, external fixation was also considered to be definitive primary stabilization because of its theoretical simplicity of application, minimal compromise of the blood supply and apparently low infection rate at the fracture site<sup>7-10</sup>.

Giannoudis et al<sup>11</sup> systematically reviewed 13 studies that investigated external fixation as the definitive treatment of open tibia fractures. A total of 536 fractures, of which 82% were Gustilo-Anderson grade-III open injuries, were included in the analysis. Union occurred in 94% and took 37 weeks on average. The overall incidence of the delayed union after 6 months was 24%. The failure rate was only 2.7%, even if 68.5% of the fractures required a re-operation before union

was achieved. The deep infection rate was 16.2% with 4.2% developing chronic osteomyelitis. The most relevant device-associated complication was, however, the high rate of pin-track infection which occurred in up to 32.2% of cases.

In the Nineties, small-diameter, unreamed, locked intramedullary nails have been introduced as an alternative for external fixation, especially in tibial shaft fractures. Giannoudis et al<sup>11</sup> included in their review 666 open fractures treated with unreamed intramedullary nail, 53% of which type III. The use of unreamed nails resulted in the union in 95%, while 33% required further surgery. The rate of delayed union was 22% and of malunion 10%. The rate of deep infection was 7%. On the other hand, the implant failure rate was significant (12.4%) due to the small diameter of unreamed nails. Even in grade-IIIB open tibia fractures, unreamed nailing did not correlate with a significantly higher risk of nonunion or deep infection in comparison with external fixation (Table II).

Henley et al<sup>12</sup> compared unreamed intramedullary nailing with external fixation in patients with II, III A and III B open tibial fractures and concluded that unreamed interlocking intramedullary nails proved more effective than half-pin external fixators with regards to maintenance of limb alignment. This study also revealed that the incidence of deep infections in open tibia fractures treated with intramedullary nailing did not strictly correlate with the Gustilo-Anderson type of the fracture (Table II).

Agrawal et al<sup>13</sup> included 30 open tibia fractures of different Gustilo-Anderson grades, all treated with unreamed intramedullary nailing with a two-year follow-up, in order to evaluate the incidence of complications. Despite a thorough debridement and an adequate primary soft tissue coverage, infections occurred in 10% of patients, all of whom

were in type III and had been operated after the golden time period interval. The results obtained in this paper show that a primary unreamed intramedullary nailing can be safely performed in the grade I e II open tibia fractures, with minimal complications and excellent functional results, and that an appropriate debridement and immediate soft tissue coverage is associated with low rates of infections, supporting the concept that a secondary wound closure is not necessary if vital soft tissues can be imported reliably into the zone of the injury.

It is still debated whether unreamed intramedullary nail is preferable to reamed one for the treatment of open tibial fractures or not. According to the most recent literature<sup>14,15</sup>, the cortical blood supply during reaming is compromised, leading to a higher nonunion and infection rate. Some benefits of unreamed intramedullary nailing are the reduced heat production in the intramedullary canal, the reduced interference of endosteal blood supply and the reduced associated bone necrosis. As shown by different experimental studies, cortical bone perfusion decrease is much higher after reamed nail insertion than after unreamed nail insertion<sup>16</sup>. Last but not least, the cortical revascularization is restored by 6 weeks in the unreamed group, but not until 12 weeks in the reamed group, which makes the latter option much more prone to infections<sup>17</sup>. Furthermore, several studies have found no statistically significant differences in terms of implant failure, fracture nonunion, malunion, and major re-operation between reamed and unreamed nails<sup>18-22</sup>.

In the belief that immediate intramedullary nailing could increase the risk of septic complications, some authors have also proposed sequential management with initial external fixation followed by secondary reamed nailing, particularly

**Table II.** Infection rate (%) in the different surgical techniques for the treatment of open tibia fractures.

|                                | No. of fractures | External Fixation | Unreamed tibial nailings (UTN) | Reamed tibial nailings (RTN) | External fixation and delayed RTN |
|--------------------------------|------------------|-------------------|--------------------------------|------------------------------|-----------------------------------|
| Giannoudis et al <sup>11</sup> | 666              | 16.2              | 7                              | 6.4                          | 17                                |
| Henley et al <sup>12</sup>     | 104              | 21                | 13                             | –                            | –                                 |
| Bhandari et al <sup>29</sup>   | 396              | 16.1              | 10.2                           | –                            | –                                 |
| Yokoyama et al <sup>23</sup>   | 99               | –                 | 4.8                            | 8.3                          | 14                                |
| Keating et al <sup>20</sup>    | 94               | –                 | 2.8                            | 4                            | -                                 |
| Maurer et al <sup>24</sup>     | 24               | –                 | –                              | –                            | 25                                |
| McGraw e Lim <sup>26</sup>     | 16               | –                 | –                              | –                            | 44                                |

for the treatment of type-III fractures. Giannoudis et al<sup>11</sup> identified four relevant clinical trials, with a total amount of 96 open tibia fractures, including 51 grade-III, treated by external fixation followed by secondary reamed intramedullary nailing. All grade-III open fractures were managed by the delayed soft-tissue cover. Union was achieved in 92% in a mean time of 38.5 weeks. In 23%, at least one further procedure was required to obtain a union or to treat serious complications. The mean duration of external fixation was 39 days. Pin-tract infection occurred in 15.3% of cases. The conversion from external fixation to reamed intramedullary nailing was performed within 26 days, always after complete healing of the pin tract. Despite this approach, the overall rate of deep infection was 17%, with 2.5% of cases developing chronic osteomyelitis. As concerned for delayed union and malunion, they occurred in 14% and in 11% of the cases respectively.

Yokoyama et al<sup>23</sup> included 99 open tibia fractures and divided them in two different groups according to the timing of intramedullary nailing, be it immediate or delayed after external fixation. According to the collected data, the authors conclude that there is a higher risk of deep infection in case of intramedullary nailing after external fixation compared to primary intramedullary nailing (5.9% vs. 14%), especially in case of pin-tract infection. They also assess that debridement within 6 hours and appropriate soft-tissue management are also important factors to prevent deep infections as second conclusion (Table II).

Maurer et al<sup>24</sup> found a very strong correlation between previous pin-tract infection and the development of deep infection after nailing. It is difficult to define an appropriate time interval between the removal of the pins and the nailing that may allow the host's defense mechanisms to eradicate any residual bacteria from the pin sites (Table II). Some experimental data suggest that a suitable period should be for at least four weeks<sup>25</sup>.

McGraw and Lim<sup>26</sup> concluded in their paper that an extended period of external fixation combined with the occurrence of pin-tract infection contributes to the onset of deep infections.

However, Antich-Adrover et al<sup>27</sup> and Blachut et al<sup>28</sup> have been able to improve the results of this sequential protocol dramatically by limiting the duration of external fixation and the associated prevalence of pin-tract infection.

In addition, Bhandari et al<sup>29</sup> recently performed a meta-analysis about infection risk in this conversion method for open tibia fractures. They

reported that lack of pin-tract infection was the most important factor in the prevention of infections, and that smaller durations of external fixation resulted in 83% reduction of infection rate compared to longer durations (>28 days) of use<sup>30</sup>.

## Conclusions

With recent advances in treatment, optimized use of antibiotics, improvement in wound care, purpose of severe open fracture treatment has shifted from the "era of limb preservation" to the "era of the preservation of function". Nevertheless, some therapeutic issues are still object of debate.

Primary intramedullary nailing is one of the most powerful tools for fixation of open tibial fractures. Current evidence shows that primary intramedullary nails are superior compared to external fixation as the definitive treatment of open long bone fractures in terms of infections, non-union, malunion, and re-operation rate. Furthermore, primary intramedullary nails are comparable to delayed intramedullary nails after external fixation in terms of union, malunion, and non-union rate, but they are associated with a lower rate of deep infection compared to delayed intramedullary nails.

There are some general principles for fixation of open tibia fractures using primary intramedullary nails. First, quality of the debridement of soft-tissues performed by an experienced surgeon is crucial: both the fracture site and the implant must be covered with viable tissues to prevent secondary necrosis of the bone leading to colonization and development of deep infection. If possible, a tension-free primary wound closure should be performed in order to reduce the risk of the implant colonization and development of deep infection.

Then, the choice of the most appropriate method of fracture stabilization must be based not only on the type of fracture according to the Gustilo-Anderson classification, but also on the type of contamination (organic material, farmyard injuries, etc.). In such cases, a staged protocol with external fixation, a repeated wound debridement, and a secondary wound closure should be applied. The conversion to intramedullary nail should be performed as soon as patient or local soft tissue condition permits.

We can assume that, by following these general principles in the management of open fractures,



intramedullary nailing results in faster soft tissue and bony healing, better biomechanical stability and lower infection rates as compared to other methods, providing many advantages in terms of time of hospitalization, costs and achievement of the best possible functional outcomes.

### Conflicts of interest

The Authors declare that they have no conflict of interests.

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