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Original article

# Intramedullary nailing for adult open tibial shaft fracture. An 85-case series

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ABSTRACT

*Introduction:* Treatment of open tibial shaft fracture is controversial due to the risk of infection. We assessed results in a continuous series of open tibial shaft fractures treated by primary intramedullary nailing.
*Hypothesis:* Factors can be determined for non-union and onset of infection following primary intramedullary nailing in open tibial shaft fracture.
*Patients and method:* A retrospective study assessed open tibial shaft fractures treated by primary intramedullary nailing between January 2007 and December 2013. Fractures were classified on the AO and Gustilo classifications. Infection rates and time to union were compared.
*Results:* Eighty-five patients (85 fractures) were included: 13 Gustilo type I, 43 type II, 19 type III-A and 10 type III-B. Eight patients had infection (9%). Healing and union were obtained after nail exchange and reaming in 5 cases, and after bone transport in 2. One patient showed non-union at last follow-up. Infection risk did not correlate with Gustilo ($p = 0.55$) or AO type ($p = 0.69$). The interval between trauma and wound debridement was significantly longer in infected patients ($p = 0.048$). Eighty-three fractures (97.6%) healed, at a mean $6.9 \pm 6.1$ months (range, 2–40). Non-union was associated with AO type ($p = 0.04$), and showed a non-significant association with Gustilo type ($p = 0.06$).
*Discussion:* Time to treatment was the only factor influencing risk of infection. Non-union was related to AO comminution grade. Primary intramedullary nailing seemed reliable if treatment was early, with rigorous debridement. The advantages then are early resumption of weight-bearing and low patient burden.
*Level of evidence:* V, retrospective study.



## 1. Introduction

Primary intramedullary nailing in open tibial shaft fracture is controversial due to risk of infection [1–3].

The classic attitude consists in primary external fixation, especially in case of severe soft-tissue lesion and/or hemodynamic instability [4]. However, this treatment incurs several problems, with pin infection rates up to 50% [5], non-union rates between 10% [6] and 41% [7], and malunion rates up to 71% [5].

Intramedullary nailing enables stable fixation, weight-bearing, simple skin coverage and low patient burden.

The present study hypothesis was that certain factors affect healing and infection after primary intramedullary nailing for open tibial shaft fracture.

The aim of the study was to assess healing and infection rates in a continuous series of primary intramedullary nailing for open tibial shaft fracture.

## 2. Patients and method

### 2.1. Patients

A single-center retrospective continuous series included patients operated on between January 2007 and December 2013, with 102 open tibial shaft fractures in 101 patients. Seven fractures were treated by external fixation; 2 of these patients (3 fractures) had multiple trauma and died in the immediate postoperative period; the other 4 fractures received secondary intramedullary nailing. Five fractures were treated by plate fixation, and 92 fractures (92 patients) by primary intramedullary nailing. Seven patients were lost to follow-up before the study minimum of 6

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months, without healing at last follow-up, and were excluded from analysis.

Only open tibial shaft fractures treated in emergency by primary intramedullary nailing were included.

Exclusion criteria comprised; age < 15 years; associated joint fracture; fracture in pathologic (tumor) or infected (osteitis) bone; primary external or plate fixation; and follow-up < 6 months.

Data were analyzed for 85 patients: 23 female, 62 male; mean age, 40.3 ± 19 years (range, 15–91 years). On the Gustilo classification [8], 13 fractures were type I, 43 type II, 19 type III-A and 10 type III-B. In 38 cases, there were associated bone and joint lesions. Seven cases showed bone defect. Fracture location was in the superior third of the tibia in 2 cases, mid-third in 32, and inferior third in 51. On the AO (*Arbeitsgemeinschaft für Osteosynthesefragen*) classification AO [9], fractures were 45 type A, 19 type B and 21 type C.

### 2.2. Surgical technique

The first step consisted in drastic debridement with resection of damaged soft tissue and devascularized bone fragments. Tibial torsion was modeled on the contralateral limb. In 37 cases the nail used was UTN™, in 26 AO™ and in 22 Expert™ (all Synthes®). Reaming was performed in 41 cases. Nail locking was static in 71 cases.

Dual antibiotic prophylaxis was implemented with amoxicillin + clavulanic acid and gentamicin in 82 cases, and with clindamycin + gentamicin 48 h in 3 cases of Gustilo II [10]. In Gustilo I fractures, mean antibiotic prophylaxis time (amoxicillin + clavulanic acid) was 3 ± 1.5 days (range, 2–7 days) associated to 24 h gentamicin. In Gustilo II and III, gentamicin was administered for 48 h. Mean amoxicillin + clavulanic acid administration time was 4 ± 2.4 days (range, 2–12 days) in Gustilo II, 5.2 ± 2.7 days (range, 2–10 days) in III-A and 12.9 ± 4.3 days (range, 8–21 days) in III-B (maintained until skin cover was achieved in III-B).

In 10 cases of Gustilo III-B, closure could not be achieved and an aspiration dressing was implemented [11], with assisted healing in 4 cases, thin skin graft in 3, and emergency flap in 3 (1 soleus at day 1, 1 fasciocutaneous at day 17, 1 dorsalis major at day 7).

Three patients (1 Gustilo II, 2 Gustilo III-A) developed secondary skin necrosis requiring a flap (2 soleus at days 21 and 48, 1 fasciocutaneous at day 60).

### 2.3. Assessment

Fractures were classified following Gustilo and the AO. Location on the shaft, any bone defect, and interval from trauma to debridement were noted, as were skin coverage procedures and time after treatment initiation.

Clinical and radiographic assessment with full-leg AP and lateral views was performed at 6 weeks, 3 months, 6 months then monthly until healing (if not achieved by 6 months), defined as bone callus uniting at least 3 cortices.

Delayed consolidation (non-consolidation at 6 months but callus progression on the following X-ray) or definitive non-union at 6 months and any procedures to promote consolidation (dynamization, change and reaming of nail) were noted. Malunion exceeding 5° frontally and/or sagittally was screened for at the time of consolidation on full-leg AP and lateral views.

Onset of sepsis was defined by CRP elevation with hyperleukocytosis and purulent effusion and/or local inflammatory signs and/or positive bacteriology at revision surgery.

**Table 1**
Deep infection rates and *p*-values.

| Factors | Deep infection | *p*-value* |
|---|---|---|
| *Gustilo type* | | |
| I | 7.7% (1/13) | $p = 0.55$ |
| II | 7% (3/43) | |
| III-A | 10.5% (2/19) | |
| III-B | 20% (2/10) | |
| *AO type* | | |
| A | 9.7% (4/45) | $p = 0.69$ |
| B | 5.3% (1/19) | |
| C | 14.3% (3/21) | |

* Fisher exact test.

### 2.4. Statistics

Correlations between onset of infection or non-union and Gustilo or AO type were analyzed on Fisher exact test.

Correlation between onset of infection and time to treatment was analyzed on parametric Student t test.

Correlation between consolidation time and Gustilo or AO type was analyzed on non-parametric Kruskal-Wallis test.

First-order risk was set at 5%. Discrete variables were reported as mean ± standard deviation (range).

## 3. Results

Eight patients (9.4%) developed deep infection, without correlation with Gustilo or AO type (Table 1).

Mean trauma-to-debridement time was 406 ± 283 minutes (range, 85–1520 min), and exceeded 6 hours in 39 cases.

Septic complications were significantly associated with trauma-to-debridement time ($p = 0.047$): mean 594 ± 398 minutes (range, 250–1520 min) with versus 387 ± 264 minutes (85–1200 min) without infection. Six of the 8 patients (75%) had > 6 hours' trauma-to-debridement time.

At last follow-up, 83 patients (97.6%) showed bone healing, at a mean 6.9 ± 6.1 months (range, 2–40 months). Non-union showed a non-significant trend with respect to extent of soft-tissue involvement ($p = 0.06$) (Table 2).

AO type correlated with time to healing ($p = 0.008$) and non-union ($p = 0.04$).

At 6 months, 28 patients (32.9%) did not show complete bone healing. Twelve showed delayed consolidation, including 4 after dynamization before 6 months, and 1 after nail change and reaming at 4 months, for infection. Sixteen (18.8%) showed non-union: 12 aseptic, 4 septic (Table 3). One septic non-union of distal tibial fracture was managed by transplantar nailing, and 2 required repeat debridement and bone resection, reaming and nail change and segmental bone transport on a nail with monoplanar external fixation (Fig. 1).

Nine of the 83 patients with bone healing at last follow-up (10.8%) presented > 5° malalignment: 7 < 10°, 2 > 10°. One patient underwent revision surgery for > 20° recurvatum, with supramalleolar osteotomy on malunion in a distal tibial fracture.

## 4. Discussion

The present results were comparable to those in the literature regarding deep infection rates after primary intramedullary nailing in open tibial shaft fracture (9.4%, compared to 6.5–12.9%, depending on the series [12–16], taking all Gustilo types together), and especially for Gustilo III-B fractures (20%, compared to 20–33% [9–14]). These rates are lower than in case of external fixation: 21.4–66.7% [5,15,16].

**Table 2**
Non-union and bone healing time, with *p*-values.

| Factors | Non-union and *p*-values *p*[*] | | Bone healing time (months) and *p*-values *p*[**] | |
|---|---|---|---|---|
| *Gustilo type* | | | | |
| I | 7.7% (1/13) | $p = 0.06$ | 5.5 ± 2.3 (3–12) | $p = 0.29$ |
| II | 16.3% (5/43) | | 6 ± 4.8 (2–29) | |
| III-A | 36.8% (7/19) | | 8.9 ± 9.4 (3–40) | |
| III-B | 40% (3/10) | | 9.2 ± 6.9 (3–23) | |
| *AO type* | | | | |
| A | 11% (5/45) | $p = 0.04$ | 5.5 ± 3.7 (2–23) | $p = 0.008$ |
| B | 21% (3/19) | | 8.8 ± 9.6 (3–40) | |
| C | 47.6% (8/21) | | 9.2 ± 5.6 (3–21) | |

[*] Fisher exact test.
[**] Kruskal-Wallis test.

**Table 3**
Surgical revision (for sepsis and assisted bone healing).

| Procedure | Gustilo I | Gustilo II | Gustilo III-A | Gustilo III-B |
|---|---|---|---|---|
| *Dynamization* | | | | |
| < 6 months | 1 (3 months) | 2 (5 months) | 5 (1–2 months, 2–3 months, 2–4 months) | |
| > 6 months (aseptic non-union) | | 5 (2–7 months, 3–10 months) | 1 (9 months) | 1 (7 months) |
| *Reaming ± nail change* | | | | |
| Sepsis < 6 months | 1 (4 months) | 3 (2–1 months, 1–3 months) | | |
| Septic non-union (> 6 months) | | | | 1 (8 months) |
| Aseptic non-union (> 6 months/negative samples) | 1 (9 months) | | 5 (1–7 months, 1–10 months, 2–11 months, 1–30 months + cancellous graft) | |
| *Other/septic context* | | | | |
| Segmental bone transport (ascension) | | | 1–6 months (defect + infection) Consolidation-18 months | 1–6 months (defect + infection) Consolidation-15 months |
| Transplantar nailing (HAN™ nail [Synthes® ]) | | | 1 (16 months) septic non-union + on-consolidated ankle osteoarthritis at last follow-up –36 months | |
| *Other* | | | | |
| Aponeurotomy/Compartment syndrome | 1 | | 1 | |
| Supramalleolar derotation osteotomy | | | | 1 |

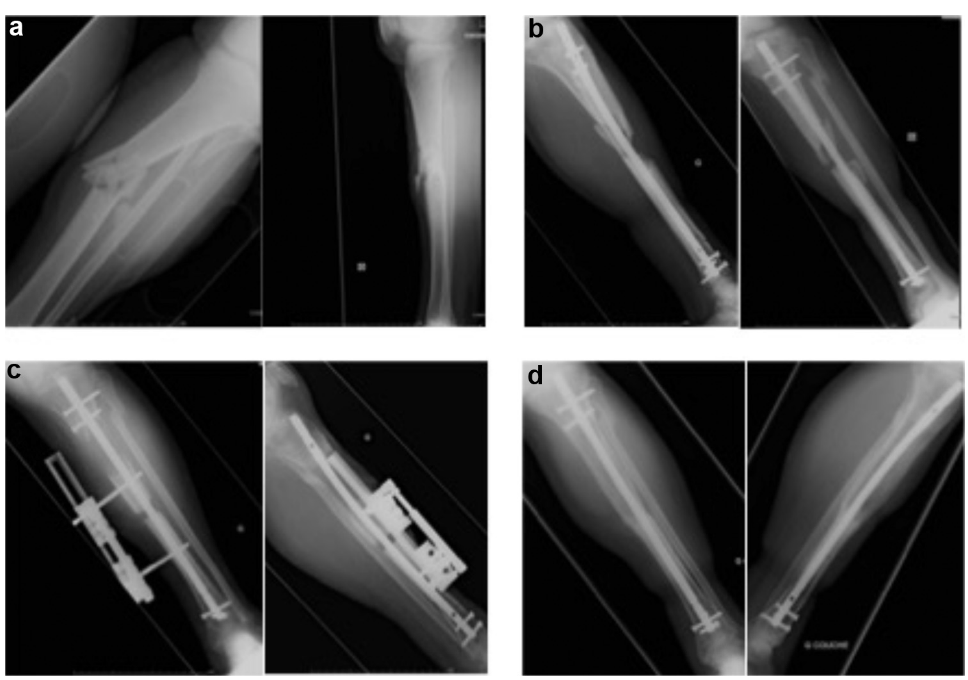


**Fig. 1.** Gustilo type III-B open tibial shaft fracture: bone transport with intramedullary nailing at 6 months. Preoperative radiograph (a). Postoperative radiograph at 2 months (b). Segmental bone transport with intramedullary nailing and monoplanar external fixator at 4 months (c). Complete bone healing at 15 months (d).

The present study involved certain limitations. It was retrospective. Inter-observer assessment of soft-tissue lesions varied, introducing a measurement bias [17]. Soft-tissue lesion severity may have been initially underestimated (3 secondary necroses), with consequent underestimation of fracture severity.

No difference in infection rates emerged according to Gustilo type or degree of comminution on the AO classification. Only the interval between trauma and debridement was significantly related to onset of deep infection. Some authors questioned the importance of operating within 6 hours of trauma [18] but, in the present series, 75% of patients with deep infection had intervals exceeding 6 hours, and it seems to us to be crucial that surgery should be initiated as soon as possible, with optimally rigorous debridement. Other factors, not tested in the present study, may have influenced onset of infection: high or low energy trauma mechanism, degree of initial wound contamination, notably from soil, and obesity or smoking [19,20].

The antibiotic prophylaxis protocol did not follow the guidelines of the French Society of Anesthesia and Intensive Care (SFAR) for open fracture and notably for Gustilo type I [21]. However, the association of a beta-lactamase to gentamicin is recommended for severely contaminated wounds and/or > 4 h treatment delay, and only 2 patients with Gustilo I fracture had less than 4 hours' interval between trauma and treatment (220 and 210 minutes, respectively). Antibiotherapy should be initiated as soon as possible [22], as should skin coverage [23]. Flap coverage was usually dependent on the availability of the plastic surgery team, and this may have affected results regarding infectious complications.

Consolidation at last follow-up was good, with a rate of 97.6%. However, there was a high rate of non-union in Gustilo III fractures, equivalent to rates for external fixation [7]. The number assisted healing procedures was high, at 25. One third of dynamization procedures were performed later than 6 months, and only 4 patients (4.7%), 3 of whom had Gustilo III-A fracture, showed aseptic non-union requiring reaming and nail change for consolidation.

We included cases with severe initial bone defect, which must have had negative impact on results for healing and non-union. However, we believe that intramedullary nailing in such cases facilitates secondary segmental bone transport [24].

## 5. Conclusion

Primary intramedullary nailing in open tibial shaft fracture seems reliable and feasible whatever the severity of skin wound and comminution. It effectively stabilizes the fracture site, facilitates skin coverage procedures and early resumption of weight-bearing, and is less burdensome for the patient than external fixation. In Gustilo type III fracture, this internal fixation technique presupposes emergency management associating early antibiotic prophylaxis, meticulous debridement and rapid skin coverage.

## Disclosure of interest

The authors declare that they have no competing interest.

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None.

## Authors' contribution

The authors all collaborated to write the article.

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