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Soft tissue coverage before 12 days prevents fracture-related infection in IIIB open tibial fractures in young and healthy patients

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Abstract

Introduction: Gustilo–Anderson type IIIB open tibial fractures carry a high risk of fracture-related infection (FRI) due to extensive soft tissue damage and frequent delays in coverage. Although early orthoplastic intervention lowers infection rates, many trauma centers lack the resources for same-day or early flap coverage. This study aimed to assess the relationship between timing of flap coverage and FRI risk in a young, healthy population, and to define a clinically relevant therapeutic window.

Materials and Methods: A retrospective cohort study was conducted at a single Level I trauma center (2012–2023). Patients with GA IIIB tibial fractures were treated under a standardized protocol with strict inclusion criteria. Timing of flap coverage was analyzed using Levene test, Student *t* test, and ROC curve analysis with the Youden index to determine the optimal infection-risk threshold.

Results: Out of 332 open tibial fractures, 41 patients with GA IIIB injuries met inclusion criteria. Mean time to coverage was 24.6 days. FRI occurred in 15 patients (36.6%). Delayed coverage was significantly associated with FRI ($P < 0.001$). ROC analysis showed an AUC of 0.83; the Youden index identified <12 days as the optimal cutoff (100% sensitivity, 34.6% specificity). None of the 10 patients treated within 12 days developed FRI, versus 56.6% in those treated later ($P < 0.05$).

Conclusions: Coverage within 12 days minimizes infection risk in GA IIIB tibial fractures. Although immediate coverage remains ideal, a defined 12-day window offers practical guidance, especially where early orthoplastic care is not feasible.

Keywords: fractures, open, tibia/injuries, surgical flaps, wound infection/prevention & control, anti-bacterial agents/therapeutic use

1. Introduction

Tibial shaft fractures are the most common long bone fractures, representing approximately 4% of all fractures,[1,2] and carry an increased risk of fracture-related infection (FRI) due to the high incidence of open injuries and limited soft tissue coverage. Up to 24% of tibial fractures are open, and among these, as many as 64% are classified as high-energy injuries (Gustilo–Anderson type III).[3,4] Type IIIB fractures, which require flap coverage for adequate soft tissue reconstruction, are associated with the highest risk of FRI, with reported rates ranging from 10% to 52% and an average incidence of approximately 25%.[5–7]

Although an orthoplastic approach has been shown to reduce the incidence of FRI, the timely availability of specialized soft tissue coverage varies significantly across trauma centers.[8,9] International guidelines recommend definitive coverage within 72 hours[10] and no later than 3–5 days after injury.[11] Early flap coverage, in particular, has been associated with improved clinical outcomes.[12,13] However, the feasibility of early coverage depends heavily on health care infrastructure, especially in resource-limited settings. Factors such as limited access to plastic surgeons, delayed referrals, and treatment in non–level I trauma centers contribute to delayed interventions.[14,15] Our group previously reported a threshold of 8 days for flap coverage in a developing country setting using a structured protocol.[16] With extended follow-up, we now define a broader therapeutic

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window based on a more stringent protocol and stricter inclusion criteria.

Moreover, many patients with GA IIIB injuries are admitted in the context of polytrauma, which may delay definitive fixation and soft tissue coverage. Others may be transferred from outside hospitals days after provisional treatment. In addition, much of the current literature includes heterogeneous patient populations, such as elderly individuals and those with significant comorbidities, factors that may confound the analysis of FRI risk.[5,7,17,18]

To address these gaps, the present study evaluates a retrospective series of GA IIIB open tibial fractures treated at a Level I trauma center under a standardized protocol. The objective is to determine whether the timing of flap coverage correlates with the development of FRI in a carefully selected cohort of young and otherwise healthy patients and whether a specific time frame can be identified as a threshold for increased infection risk.

2. Methods

A retrospective cohort study was conducted on patients treated at a single trauma center between January 2012 and July 2023. The analysis included patients with Gustilo–Anderson IIIB open tibial fractures and a minimum of 12 months of follow-up.

Exclusion criteria were (Fig. 1) more than 24 hours from injury to debridement, debridement performed at another institution or by an inexperienced surgeon, interval between debridements greater than 5 days, delay of the first intravenous antibiotic dose beyond 6 hours, suspension of antibiotic coverage before flap surgery, limb amputation due to flap failure, failure of the initial flap requiring revision surgery, definitive osteosynthesis performed at another institution, delay from osteosynthesis to flap coverage of more than 3 days, segmental bone defects exceeding 5 cm, and patients transferred from another facility.

Exclusion criteria
>24 hours from injury to debridement
Debridement performed at another institution or by inexperienced surgeon
Gap between surgical debridement higher than 5 days
Delay of first intravenous antibiotic dosage over 6 hours
Suspension of antibiotic coverage before flap surgery
Limb amputation due to flap failure
Failure of initial flap requiring revision flap surgery
Definitive osteosynthesis performed at another institution
Delay from osteosynthesis to flap higher than 3 days
Segmental bone defects exceeding 5 cm
Patients transferred from another facility
Loss of follow-up

Figure 1. Exclusion criteria.

All patients were managed according to a standardized institutional protocol. Upon arrival, immediate intravenous antibiotic administration was initiated, consisting of a first-generation cephalosporin (cefazolin) combined with an aminoglycoside (gentamicin). Clindamycin was used in cases of known penicillin allergy. Gentamicin was administered for a maximum of 72 hours to reduce the risk of nephrotoxicity and other aminoglycoside-related complications. The remaining antibiotic regimen was continued until definitive soft tissue coverage was achieved.

After antibiotic administration, and after imaging and resuscitation when needed, the Lower Limb Trauma Unit (LLTU) assumed responsibility for definitive surgical care. Surgical debridement and external skeletal stabilization were performed in most cases within 12 hours of admission, and in all cases within 24 hours. The following day, the plastic surgery team was consulted to plan complex flap coverage. In the interim, serial surgical debridements were performed every 2–3 days, and vacuum dressings were used as provisional coverage in most cases.

In coordination with the plastic surgery team, definitive fracture fixation was performed either on the same day as soft tissue coverage or up to 48 hours beforehand. In most cases, the gentamicin-coated Johnson & Johnson tibial nail (EXPERT Tibial Nail PROtect, DePuy Synthes, Warsaw, IN) was used according to our standard of care.[19] In a few cases, the TRI-Gen nail was used (Smith & Nephew, London, United Kingdom). For fractures with articular involvement, small 3.5-mm third-tubular plates and 3.5- or 2.7-mm screws were used for reduction and supplemental fixation. Coverage was achieved using either free vascularized flaps or local rotational flaps.

The primary outcome was the occurrence of FRI, assessed according to the 2018 consensus definition.[20]

Statistical analysis included Levene test to assess variance homogeneity in flap timing. A Student t test evaluated the association between time to coverage and FRI development. Receiver Operating Characteristic (ROC) curve analysis and the Youden Index were used to identify the flap timing associated with the lowest infection risk. A P-value <0.05 was considered statistically significant. All analyses were conducted using R version 4.3.1 (The R Foundation for Statistical Computing, 2023). This research has the approval of the Hospital Clínico Mutual de Seguridad (HCMS) Ethical Committee.

3. Results

Out of the 332 open fracture cases, 75 were classified as GA IIIB (9.3% of all fractures). Not all patients underwent early definitive surgery due to compromised general medical conditions. Among the GA IIIB patients, 21 developed FRI, representing 28% of this group. A total of 41 patients met the inclusion criteria (Fig. 2). Out of the 34 excluded patients (Table 1), 27 were excluded due to protocol deviations. The most frequent reasons were first debridement performed at another institution or by an inexperienced surgeon, followed by delays exceeding 24 hours from injury to initial debridement. The remaining 7 were excluded due to limb amputation secondary to flap failure, and patients with segmental bone defects more than 5 cm. Due to the protocol violations, these patients did not undergo the 12-month follow-up required for FRI assessment. Given the delayed nature of FRI and the limited follow-up in this group, we chose not to perform a statistical analysis to avoid biased interpretation.

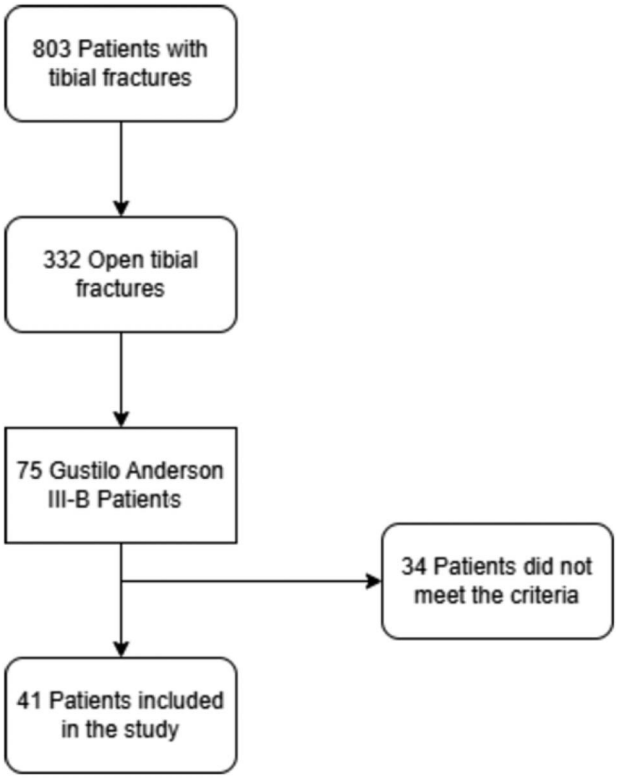

Figure 2. Patient selection flowchart.

The mean age was 38.9 years (SD = 9.5), and all were male. Comorbidities were not systematically recorded, but no significant prior medical conditions were noted.

The mean time from injury to flap coverage was 24.6 days (SD = 22.48), with a median of 20 days and an interquartile range of 17 days. Fifteen of the 41 patients developed FRI. Among them, the mean time to flap coverage was 30.8 days (SD = 14.5). The remaining 26 patients had a mean time to flap coverage of 16.1 days (SD = 8).

Variance heterogeneity was confirmed, and Student *t* test revealed a statistically significant correlation between time to coverage and FRI risk ($P < 0.001$). The area under the ROC curve was 0.83, and the cutoff value predicting FRI according to the Youden Index was <12 days (sensitivity = 100%, specificity = 34.6%) (Table 2).

Using this 12-day cutoff, the infection rate was evaluated. Among the 10 patients who underwent flap coverage within 12 days of injury, none developed an infection. In contrast, among the 31 patients who received coverage after 12 days, 15 developed FRI (56.6%). This difference was statistically significant (χ^2 test, $P < 0.05$).

Table 1

Distribution of excluded patients.

Reason for exclusion	Number of patients
First debridement at another institution or by an inexperienced surgeon	9
First debridement performed more than 24 h after injury	5
Interval between debridements greater than 72 h	4
Limb amputation due to flap failure*	4
Delay from definitive fixation to flap coverage	4
Delay in administration of first antibiotic dose	3
Segmental bone defect >5 cm*	3
Antibiotic suspension before soft tissue coverage	1
Definitive osteosynthesis performed at another institution	1
Total	34

* Patients excluded due to injury characteristics, such as flap failure or extensive bone loss, rather than protocol deviations.

4. Discussion

Open fractures with severe soft tissue damage represent a substantial global health burden,[5] with FRI being a major complication that significantly increases health care costs, nearly quadrupling expenditures.[21] Early definitive soft tissue coverage and fracture fixation are the standard of care to reduce FRI and optimize bone healing.

Clinical outcomes from such protocols have consistently shown reduced infection rates in high-grade open fractures.[9–11,22] However, the optimal timing of soft tissue coverage remains controversial, with recommendations ranging from 48 hours to 28 days postinjury.[8,10,12–14,16,18,22–25] These differences often reflect systemic and logistical constraints rather than clinical discretion. Factors such as polytrauma,[26–28] medical comorbidities, and initial treatment at regional hospitals contribute to delayed interventions.

Ideally, early coordinated care between orthopaedic and plastic surgery units, the "fix and flap" approach, should occur as soon as possible. However, in many resource-limited settings, timely transfer to Level I centers and early orthoplastic collaboration is often unfeasible.[23,29] ACS/OTA/AO guidelines recommend flap coverage within 7 days for GA IIIB tibial fractures.[25]

Our study supports these principles but also identifies a practical threshold. Flap coverage within 12 days was associated with no observed FRIs, whereas coverage beyond this point resulted in a 56% infection rate. This difference was statistically significant, underscoring the link between delayed coverage and increased FRI risk.

Previously, our group identified an 8-day window for safe coverage.[16] In this updated series, we applied stricter inclusion criteria focusing on younger, healthier patients to minimize confounding factors. This resulted in a 4-day extension of the "safe window," suggesting that host factors such as general health may modulate infection risk. Nevertheless, this should not be interpreted as an endorsement of delayed coverage. Early intervention remains the gold standard, and our "as early as possible" orthoplastic approach remains fundamental.

Our ability to maintain a low FRI incidence despite delayed coverage may reflect the impact of adjunctive strategies, including meticulous serial debridement, negative-pressure wound therapy, appropriate antibiotic prophylaxis, and routine use of gentamicin-coated nails (EXPERT Tibial Nail PROtect, DePuy Synthes, Warsaw, IN), consistent with our previously published protocol.[19]

There is a need for context-appropriate, reproducible protocols in developing regions where early fix and flap is not always feasible. The lack of international guidelines addressing delayed timing represents a critical gap.

Table 2

Cutoff days for mitigating FRI.

	Sensitivity	Specificity
<12 d	100%	34.6%

This study has limitations: it is retrospective, has a relatively small sample size, and limited follow-up. In addition, although we considered analyzing infection rates in the excluded patients, most were not followed for the full 12 months due to protocol noncompliance. Attempting to infer outcomes in this subgroup would be speculative and risk misleading conclusions; we, therefore, chose not to include this analysis but reported their distribution to maintain transparency.

However, our strict exclusion criteria yielded a homogeneous population of young, otherwise healthy patients who may suffer more severe injuries yet have stronger physiological recovery potential.

5. Conclusions

Fracture-related infection in GA IIIB open tibial fractures is influenced by multiple factors, with flap timing emerging as a key determinant. Ideally, flap coverage and definitive fixation should occur on the same day as the injury. However, in real-world settings, staged procedures may be necessary due to polytrauma or limited resources.

Our findings confirm the correlation between timely flap intervention and infection risk. In our cohort, coverage within 12 days remained effective in preventing infection. This supports the development of standardized protocols that include early antibiotic prophylaxis, repeated surgical debridement, advanced wound dressing, and fracture stabilization with local antibiotic delivery.

Given the constraints in many institutions, future research should focus on strategies to reduce FRI when early orthoplastic intervention is not feasible. Promising areas include technologies for improved wound care and local delivery systems that prevent bacterial colonization and biofilm formation.

Data Availability Statement

The datasets generated during and/or analyzed during the current study are not publicly available but are available from the corresponding author on reasonable request.

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