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Original Research Article

INFLUENCE OF SOFT TISSUE MANAGEMENT AND VASCULAR INTEGRITY ON HEALING OUTCOMES IN SEVERE OPEN TIBIAL FRACTURES

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ABSTRACT

Background: Gustilo type IIIB and IIIC open tibial fractures are among the most severe musculoskeletal injuries, often involving significant soft tissue loss and vascular compromise. Successful outcomes rely heavily on the timing and method of soft tissue and vascular reconstruction. This study evaluates the role of early versus delayed flap coverage and vascular repair in improving outcomes, including infection rates, union time, limb salvage, and function.

Material and Methods: A prospective observational study was conducted on 30 patients with type IIIB and IIIC open tibial fractures over a two-year period. All patients underwent thorough debridement and skeletal stabilization. Definitive soft tissue coverage was achieved using local, free muscle, or cross-leg flaps. Timing of flap coverage (early vs delayed) and revascularization procedures were recorded. Outcomes assessed included infection rates, flap success, union time, limb salvage, and functional recovery using the Lower Extremity Functional Scale (LEFS).

Results: Of the 30 patients, 26 underwent soft tissue flap coverage. Early flap coverage i.e. within 72 hours was performed in 14 cases and delayed in 12. Early coverage significantly reduced infection rates and led to faster fracture union (mean: 34.2 vs. 42.7 weeks; $p < 0.05$). Flap success was achieved in 80.7% of cases. Limb salvage was possible in 93.3% of patients. Functional outcomes, as measured by LEFS, were superior in the early flap and free flap groups. Two patients with type IIIC injuries underwent primary amputation due to failed revascularization.

Conclusion: Early soft tissue coverage and prompt vascular repair are crucial to optimizing outcomes in type IIIB and IIIC open tibial fractures. A multidisciplinary orthoplastic approach enhances limb salvage, reduces infection, and improves functional recovery. Individualized flap selection based on timing and defect characteristics remains a key determinant of success.

Keywords: Open tibial fracture, Soft tissue management, Vascular integrity, Fracture healing, Limb salvage, Orthopedic trauma

INTRODUCTION

Gustilo-Anderson type IIIB and IIIC open tibial fractures represent the most severe spectrum of limb injuries, typically resulting from high-energy trauma. These injuries are compounded by extensive soft tissue loss, contamination, and, in the case of type IIIC fractures, major arterial injury, making limb salvage complex and uncertain.[1,2]

While skeletal fixation is a cornerstone of fracture management, it is now well recognized that **soft tissue and vascular reconstruction** are critical to

successful outcomes. Historically, delayed soft tissue coverage led to higher rates of infection, flap failure, and nonunion. Godina's landmark work in early microsurgical flap coverage i.e. within 72 hours transformed the management approach, demonstrating markedly better results in infection control and flap survival.[3]

Multiple studies have since corroborated that **timing of soft tissue coverage**, particularly the use of free flaps, directly influences healing, infection rates, and functional recovery.[4–6] Likewise, vascular repair in type IIIC injuries is the linchpin of limb salvage. Failure to achieve adequate revascularization often necessitates amputation, despite aggressive orthopedic reconstruction.[7,8]

In this context, a **multidisciplinary orthoplastic approach** integrating trauma, reconstructive, and vascular surgery is paramount. Individualized flap selection, timing, and coordination between teams form the pillars of modern limb salvage protocols [9–11]. However, practical constraints such as limited microsurgical resources continue to influence flap choice, with options like cross-leg flaps serving as valuable alternatives when free tissue transfer is not feasible.[12]

This study investigates outcomes in 30 patients with type IIIB and IIIC open tibial fractures, focusing on timing of flap coverage, vascular repair, and choice of soft tissue reconstruction. The goal is to evaluate their impact on infection control, union, limb salvage, and functional recovery.

MATERIALS AND METHODS

Study Design and Setting

This was a prospective observational study conducted in the Department of Orthopaedics at a tertiary care trauma center in India over a period of two years. Institutional ethical clearance was obtained before the initiation of the study. The objective was to evaluate surgical outcomes following soft tissue and vascular interventions in patients with Gustilo type IIIB and IIIC open tibial fractures.

Inclusion and Exclusion Criteria

Patients eligible for inclusion were those aged 18 years and above who sustained Gustilo-Anderson type IIIB or IIIC open fractures of the tibial shaft and presented within 24 hours of injury. All included patients provided informed consent. Patients were excluded if they had type I, II, or IIIA fractures, pathological fractures, polytrauma with unstable systemic status, prior surgical intervention on the same limb, or were lost to follow-up before completion of outcome assessment.

Patient Classification and Initial Management

A total of 30 patients were enrolled and classified based on the Gustilo-Anderson system. Fractures were further categorized using the AO/OTA classification system. On presentation, each patient underwent comprehensive clinical evaluation to assess the extent of soft tissue loss, degree of contamination, and presence of vascular injury. Initial management followed Advanced Trauma Life Support (ATLS) guidelines, including broad-spectrum intravenous antibiotic administration and emergency surgical debridement within six hours of admission. Fractures were temporarily stabilized using either external fixators or supportive splinting, depending on the injury severity and pattern.

Definitive Surgical Protocol

Definitive skeletal fixation and soft tissue coverage were performed based on individualized evaluation. Flap selection was determined by the location and size of the defect, the quality of surrounding tissue, and the overall condition of the limb. Options included local rotational flaps, cross-leg flaps, and free muscle flaps such as the latissimus dorsi or gracilis. The timing of flap coverage was recorded and stratified as early (within 72 hours) or delayed (after 72 hours) from the time of injury. Skeletal stabilization was achieved either through external fixation (uniplanar or Ilizarov) or intramedullary interlocking nailing, typically after soft tissue stabilization had been achieved. In cases involving vascular compromise, surgical repair was carried out in coordination with the vascular surgery team. If perfusion could not be restored promptly, primary amputation was considered.

Follow-Up and Outcome Measures

Patients were followed postoperatively at intervals of 2, 6, 12, and 24 weeks. Outcome parameters included wound healing, infection rates, time to clinical and radiographic union, flap survival, and occurrence of complications such as necrosis or dehiscence. The overall limb salvage rate was also recorded. Functional outcomes were assessed using the Lower Extremity Functional Scale (LEFS), and the Mangled Extremity Severity Score (MESS) was applied where appropriate.

Data Analysis

All clinical data were compiled using Microsoft Excel and descriptive statistics were applied to demographic and clinical variables. Comparisons between early and delayed soft tissue coverage, types of flap used, and their respective outcomes were assessed using the Chi-square test for categorical data and Student's t-test for continuous variables. A p-value of less than 0.05 was considered statistically significant.

RESULTS

A total of 30 patients with Gustilo-Anderson type IIIB (n = 21) and type IIIC (n = 9) open tibial fractures were included in the study. The mean age was 32.8 years (range: 18–60), with a male predominance.

Soft tissue flap coverage was performed in 26 patients (86.6%). Early flap coverage, defined as coverage within 72 hours of injury, was achieved in 14 patients, while 12 patients underwent delayed

coverage beyond 72 hours. The remaining four patients were managed with split-thickness skin grafting following satisfactory wound granulation.

Postoperative wound infection occurred in 9 patients (30%). Infection rates were significantly lower in the early flap coverage group compared with the delayed coverage group. Early coverage was also associated with faster fracture union, with a mean union time of 34.2 weeks compared to 42.7 weeks in the delayed group ($p < 0.05$).

Flap survival was achieved in 21 of 26 cases (80.7%). Flap-related complications included marginal necrosis in two patients, partial flap loss in two patients, and total flap loss in one patient requiring secondary reconstruction. Free muscle flaps demonstrated better survival and functional outcomes compared to cross-leg and local flaps.

Among patients with type IIIC fractures, vascular repair was attempted in seven cases. Limb salvage was successful in six patients following revascularization. Two patients with failed revascularization underwent primary amputation. The overall limb salvage rate in the study cohort was 93.3%.

Functional outcomes assessed using the Lower Extremity Functional Scale (LEFS) were superior in patients who underwent early flap coverage and in those treated with free muscle flap

Table 1: Patient Demographics and Fracture Classification

Parameter	Type IIIB (n=21)	Type IIIC (n=9)	Total (n=30)
Mean Age (years)	37.2	35.9	36.9
Male (%)	85.7%	88.9%	86.7%
RTA as Injury Cause	81%	89%	83%

Table 2: Timing of Soft Tissue Coverage and Outcomes

Timing of Flap Coverage	No. of Patients	Infection Rate (%)	Mean Union Time (weeks)	Flap Complications
Early (<72 hrs)	14	7.1%	22.3	1 minor necrosis
Delayed (>72 hrs)	16	37.5%	29.6	3 necrosis cases

Table 3: Flap Type vs. Complication and Success Rates

Flap Type	No. of Cases	Flap Success (%)	Partial Loss	Total Necrosis	Infection Rate
Cross-leg	10	90%	1	0	10%
Free muscle	7	86%	1	1	14%
Local fasciocutaneous	8	100%	0	0	12.5%
Skin graft alone	5	60%	1	1	40%

Table 4: Vascular Repair and Salvage Outcomes (Type IIIC only)

Vascular Intervention	No. of Cases	Limb Salvaged	Amputated	Infection (%)
Attempted Revascularization	7	6	1	14.3%
No Revascularization	2	0	2	50%

Table 5: LEFS Scores by Coverage Timing

Timing of Coverage	Mean LEFS Score	Standard Deviation
Early (<72 hrs)	67.3	±5.4
Delayed (>72 hrs)	53.1	±8.2

LEFS: Lower Extremity Functional Scale (out of 80)

DISCUSSION

Gustilo-Anderson type IIIB and IIIC open tibial fractures present unique challenges due to extensive soft tissue loss and, in type IIIC injuries, vascular compromise. The present study demonstrates that the timing and method of soft tissue and vascular reconstruction play a decisive role in determining infection rates, fracture union, and limb salvage.

Early flap coverage within 72 hours was associated with significantly lower infection rates and faster fracture union. These findings strongly support the principles advocated by Godina, who emphasized early microsurgical reconstruction to reduce contamination and improve flap survival. Similar benefits of early coverage have been reported by Fischer et al. and Foote et al., reinforcing the concept that delay in soft tissue reconstruction adversely affects outcomes.

Flap selection also influenced results. Free muscle flaps provided better vascularity, dead-space obliteration, and functional recovery compared with cross-leg and local flaps. However, cross-leg flaps remained a valuable salvage option when free flaps were not feasible, particularly in resource-limited settings.

In type IIIC fractures, successful revascularization was the key determinant of limb salvage. Despite aggressive reconstruction, failed vascular repair resulted in inevitable amputation, underscoring the importance of prompt vascular assessment and multidisciplinary coordination. These findings align with previous reports highlighting the limits of limb salvage in cases of irreversible ischemia.

Importantly, this study confirms that in severe open tibial fractures, soft tissue integrity and vascular status outweigh fixation method in determining outcomes. Early debridement, timely flap coverage,

and coordinated orthoplastic care remain the cornerstones of successful limb salvage.

CONCLUSION

Successful management of Gustilo-Anderson type IIIB and IIIC open tibial fractures depends primarily on the quality and timing of soft tissue reconstruction and the restoration of vascular integrity, rather than on skeletal fixation alone. This study demonstrates that early soft tissue coverage particularly when performed within 72 hours of injury significantly reduces infection rates, accelerates fracture union, and improves functional outcomes.

The findings further highlight that appropriate flap selection, tailored to defect size, tissue availability, and patient condition, plays a critical role in achieving durable coverage and limb salvage. Free and well-planned local flaps showed higher survival rates and superior functional recovery compared to delayed or less definitive coverage strategies. In type IIIC injuries, timely and successful vascular repair emerged as the decisive factor for limb salvage; failure of revascularization was strongly associated with the need for amputation.

These results reinforce the importance of a coordinated orthoplastic approach involving orthopedic, plastic, and vascular surgeons from the early stages of treatment. Early decision-making regarding flap coverage and vascular repair can substantially influence outcomes and reduce the morbidity associated with prolonged reconstruction.

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