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ORIGINAL ARTICLE

Fix and Flap for Open Gustilo-Anderson Type II and III Tibial Fractures: A Prospective Observational Study of Anatomical and Functional Outcomes

Harri Vishnu M,¹  T. Thirumalaiswamy² and Senthil C^{3,*}

¹*Professor, Department of Orthopaedics, Dhanalakshmi Srinivasan Medical College and Hospital, Siruvachur, Tamil Nadu*

²*Associate Professor, Department of General Surgery, Dhanalakshmi Srinivasan Medical College, Siruvachur, Tamil Nadu*

³*Postgraduate, Department of Orthopaedics, Dhanalakshmi Srinivasan Medical College and Hospital, Siruvachur, Tamil Nadu*

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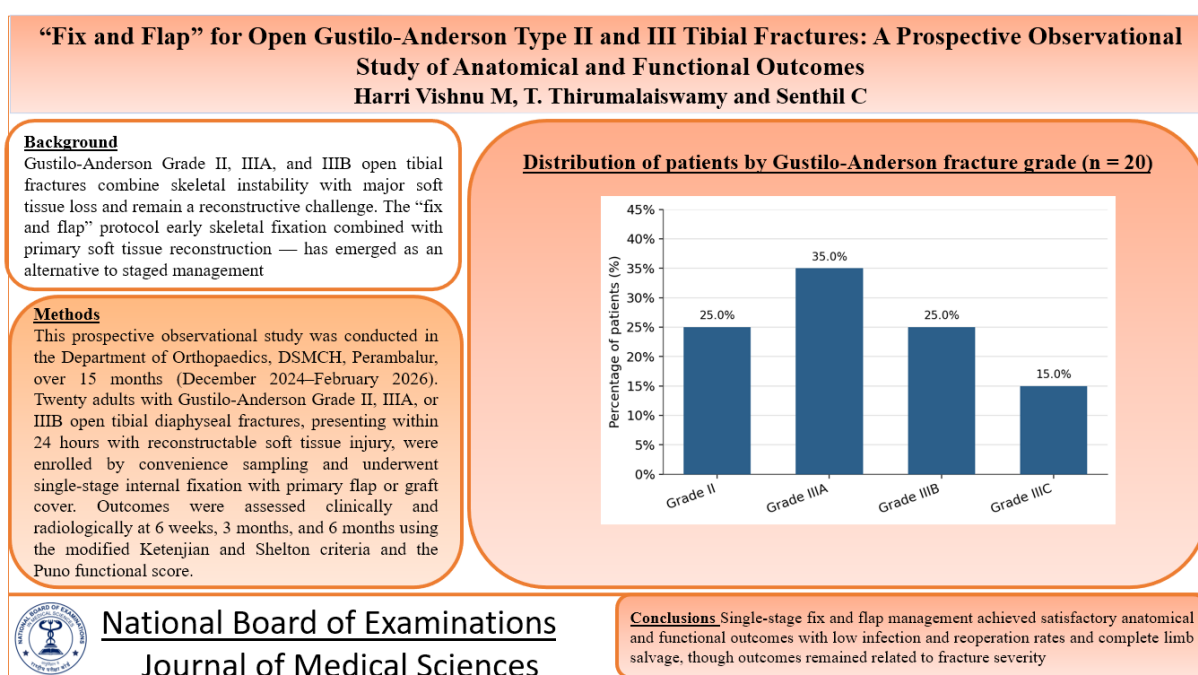
Abstract

Background: Gustilo-Anderson Grade II, IIIA, and IIIB open tibial fractures combine skeletal instability with major soft tissue loss and remain a reconstructive challenge. The “fix and flap” protocol early skeletal fixation combined with primary soft tissue reconstruction — has emerged as an alternative to staged management. **Materials and Methods:** This prospective observational study was conducted in the Department of Orthopaedics, DSMCH, Perambalur, over 15 months (December 2024–February 2026). Twenty adults with Gustilo-Anderson Grade II, IIIA, or IIIB open tibial diaphyseal fractures, presenting within 24 hours with reconstructable soft tissue injury, were enrolled by convenience sampling and underwent single-stage internal fixation with primary flap or graft cover. Outcomes were assessed clinically and radiologically at 6 weeks, 3 months, and 6 months using the modified Ketenjian and Shelton criteria and the Puno functional score. Data were analysed using IBM SPSS v26. **Results:** Mean age was 40.30±8.57 years; Grade IIIA fractures were most common (35%). Mean time to soft tissue cover was 47.45±12.58 hours and mean time to radiological union was 23.30±3.64 weeks. Fasciocutaneous flaps were used in 35% of patients. Complications occurred in 45% of patients (osteomyelitis 10%, deep infection 10%, restricted knee motion 10%, superficial infection 5%, nonunion 5%, delayed union 5%), and 10% required reoperation. At 6 weeks, 60% achieved full weight-bearing. Functional outcome was excellent in 20%, good in 30%, fair in 30%, and poor in 20% (80% satisfactory), with 100% limb salvage and no mortality. **Conclusion:** Single-stage fix and flap management achieved satisfactory anatomical and functional outcomes with low infection and reoperation rates and complete limb salvage, though outcomes remained related to fracture severity.

Keywords: Fix and flap, Gustilo-Anderson classification, open tibial fracture, soft tissue reconstruction, functional outcome

*Corresponding Author: Senthil C
Email: drcs28183@gmail.com

Graphical Abstract



Introduction

Open fractures of the tibia are among the most challenging injuries encountered in orthopaedic trauma practice. The tibia is the most frequently fractured long bone, and its subcutaneous anteromedial surface renders it particularly vulnerable to exposure following high-energy trauma such as road traffic accidents and falls from height [1]. The Gustilo-Anderson classification remains the most widely used system for grading the severity of open fractures and guiding management; Type II and Type III (IIIA and IIIB) injuries are characterised by extensive soft tissue loss, periosteal stripping, contamination, and occasionally segmental bone loss, and typically require a multidisciplinary approach for an optimal outcome [2].

Conventional management of open tibial fractures has followed a staged protocol — debridement, temporary external fixation, and delayed wound cover once the wound bed is considered clean [3].

This delay in soft tissue coverage has been associated with an increased risk of infection, nonunion, prolonged hospitalisation, and inferior functional recovery, particularly given the tibia's comparatively poor soft tissue envelope and vascularity [4].

Godina's work in the 1980s demonstrated that early microsurgical reconstruction, ideally within 72 hours of injury, reduced infection and nonunion rates compared with delayed coverage [5]. Building on this principle, Gopal et al. described the “fix and flap” protocol, combining definitive skeletal fixation with primary soft tissue reconstruction, usually within the first three days of injury, converting an open wound into a closed one at the earliest opportunity [6]. Single-stage combined orthopaedic and plastic surgical management — the “orthoplastic” approach — has since been associated with a reduced hospital stay and fewer

complications compared with staged protocols [7,8].

The timing of definitive coverage continues to be debated. Byrd et al. proposed a timing-based classification of acute (<72 hours), subacute (72 hours to 3 months), and chronic (>3 months) reconstruction, and reported superior outcomes with earlier intervention [9]. International guidelines now recommend that patients with severe open fractures be assessed jointly by orthopaedic and plastic surgical teams, ideally within 24 hours of injury, to enable coordinated single-stage management [7,10].

Despite growing evidence favouring the fix and flap approach, prospective outcome data from Indian tertiary care settings remain limited. This study was undertaken to evaluate the anatomical and functional outcomes of Gustilo-Anderson Grade II, IIIA, and IIIB open tibial fractures managed by early locking intramedullary nailing or plating combined with primary soft tissue reconstruction, and to document the methods of soft tissue reconstruction employed.

Materials and Methods

Study design, setting, and duration

This prospective observational study was conducted in the Department of Orthopaedics, Dhanalakshmi Srinivasan Medical College and Hospital (DSMCH), Perambalur, Tamil Nadu, India, over 15 months (December 2024 to February 2026), to assess the anatomical and functional outcomes of open Gustilo-Anderson Grade II and IIIA/IIIB tibial fractures managed by the fix and flap protocol — early skeletal stabilisation with locking intramedullary interlocking nailing or plating, combined with primary soft tissue reconstruction.

Study population Sample size and sampling

Study population included patients presenting with Tibial fractures. A formal sample size calculation was not performed, as this was an exploratory prospective observational study. All consecutive eligible patients fulfilling the inclusion and exclusion criteria and presenting during the predefined 15-month study period were included. Adults (>20 years) presenting within 24 hours of injury with high-grade open tibial diaphyseal fractures (Gustilo-Anderson Grade II, IIIA, or IIIB) and primarily reconstructable soft tissue injury were included. Patients with open growth plates, intra-articular extension into the proximal or distal tibia, Grade IIIC fractures with vascular compromise, grossly contaminated or non-reconstructable wounds, or those who declined consent were excluded. A total of 20 patients were enrolled by convenience sampling, representing the complete cohort available during the study period.

Ethical considerations

Institutional Ethics Committee approval was obtained prior to commencement of the study. Written informed consent was obtained from all participants (or their legal guardians, where applicable) after explaining the study objectives, procedures, risks, and benefits. Participation was voluntary, and confidentiality of patient data was maintained throughout.

Procedure and postoperative care

A semi-structured proforma was used to record sociodemographic data, mechanism and timing of injury, fracture classification, intraoperative findings, and postoperative outcomes. All patients

underwent initial debridement followed by internal fixation with a locking intramedullary nail or plate, as appropriate to the fracture pattern, with primary soft tissue cover provided in the same stage using local, regional, or free flaps, or split-thickness skin grafting, depending on the extent of the defect. Postoperatively, patients received broad-spectrum intravenous antibiotics, routine wound inspection and dressing, and early mobilisation and physiotherapy guided by fixation stability and flap healing. Follow-up clinical and radiological assessment was performed at 6 weeks, 3 months, and 6 months.

Outcome measures

Anatomical outcome was assessed by time to radiological union on serial radiographs and the occurrence of complications (infection, malunion, nonunion). Functional outcome was assessed using the Puno functional score and the modified Ketenjian and Shelton criteria (as modified by Yokoyama), incorporating pain, range of motion, strength, residual deformity, activities of daily living, and sensation.

Statistical analysis

Data were entered in Microsoft Excel and analysed using IBM SPSS version 26. Descriptive statistics (mean, standard deviation, frequency, percentage) summarised the data; the chi-square test was used for categorical variables and the paired t-test/Wilcoxon signed-rank test for pre- and post-intervention comparisons. A p-value <0.05 was considered statistically significant.

Results

Twenty patients with Gustilo-Anderson Grade II, IIIA, IIIB, or IIIC open tibial fractures were studied. The majority (60%) were aged 40–49 years (mean age 40.30 ± 8.57 years), with an equal male:female distribution (10:10, 50% each). Left-hand dominance was present in 65% of patients, while the right limb was more frequently injured (60%). Self-fall (40%) was the leading mechanism of injury, followed by assault (35%) and road traffic accidents (25%). Associated injuries were present in 45% of patients, most commonly multiple fractures (44.4%). (Table 1)

Table 1. Sociodemographic and injury characteristics (n = 20)

Variable	Category	n	%
Age group (years)	20–29	4	20.0
	30–39	2	10.0
	40–49	12	60.0
	>49	2	10.0
Sex	Male	10	50.0
	Female	10	50.0
Affected side	Right	12	60.0
	Left	8	40.0

Variable	Category	n	%
Cause of injury	Self-fall	8	40.0
	Assault	7	35.0
	Road traffic accident	5	25.0
Associated injuries	Present	9	45.0
	Absent	11	55.0

Grade IIIA injuries were the most common (35%), followed by Grade II and Grade IIIB (25% each) and Grade IIIC (15%) (Figure 1). On AO/OTA

classification, types 42-A2 and 43-B1 were most frequent (20% each), followed by 43-C1 (15%) (Table 2).

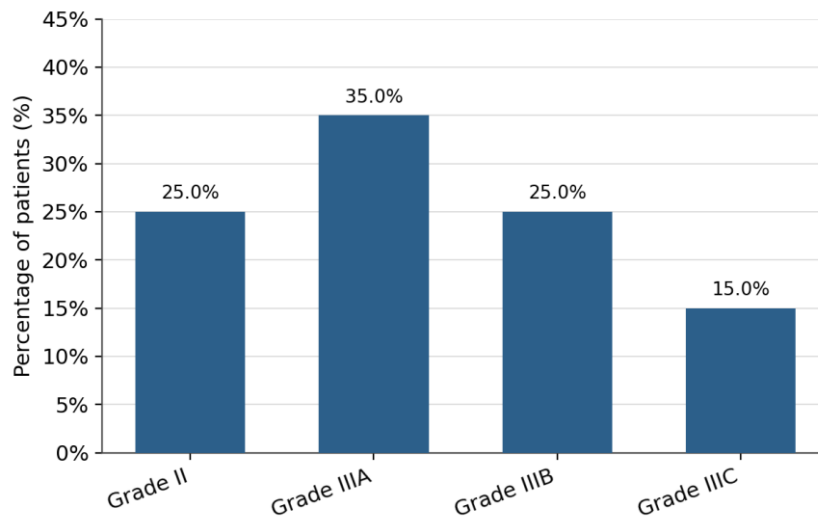


Figure 1. Distribution of patients by Gustilo-Anderson fracture grade (n = 20)

Table 2. AO/OTA fracture classification (n = 20)

AO/OTA type	n	%
42-A2	4	20.0
43-B1	4	20.0
43-C1	3	15.0
Other types (combined)	9	45.0

Fasciocutaneous flaps were the most frequently used method of soft tissue reconstruction (35%), followed by muscle pedicle flaps (25%); primary closure and split-thickness skin grafting each accounted

for 20% (Figure 2). Soft tissue cover was achieved immediately (within 24 hours) in 35% of patients and early (within 72 hours) in a further 45%, with the mean time to cover being 47.45 ± 12.58 hours (Table 3).

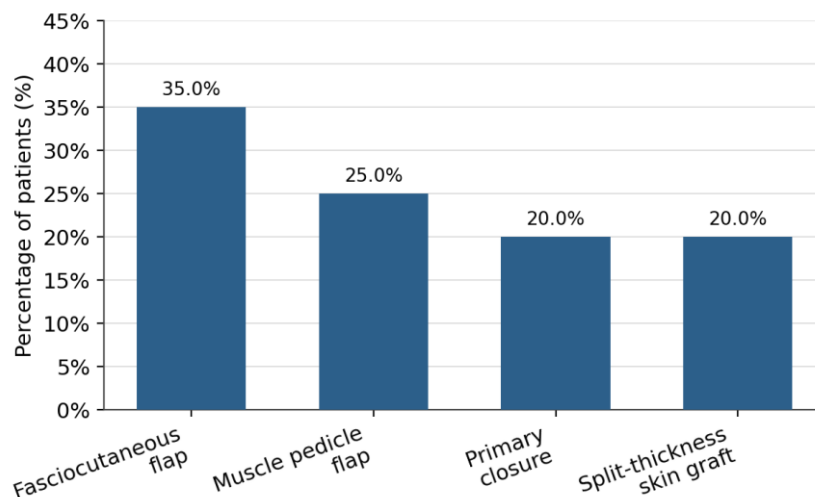


Figure 2. Method of soft tissue reconstruction (n = 20)

Table 3. Timing of soft tissue cover (n = 20)

Timing of cover	n	%
Immediate (<24 h)	7	35.0
Early (24–72 h)	9	45.0
Delayed (>72 h)	4	20.0

Fifty-five per cent of patients had no complications. Deep infection, osteomyelitis, and restricted knee motion each occurred in 10% of patients, while superficial infection, nonunion, and

delayed union each occurred in 5% (Figure 3). Reoperation was required in 10% of patients (2 of 20). There were no mortality and no amputation in this series.

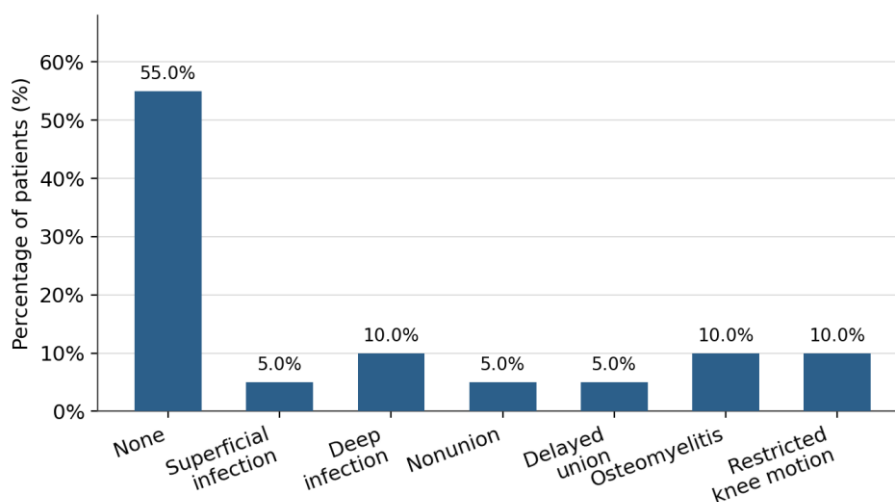


Figure 3. Postoperative complications (n = 20)

At 6 weeks, 60% of patients had achieved full weight-bearing, 15% partial weight-bearing, and 25% remained non-weight-bearing. Physiotherapy compliance was good in 55%, moderate in 30%, and poor in 15% of patients (Table 5). By the

modified Ketenjian and Shelton criteria, functional outcome was excellent in 20%, good in 30%, fair in 30%, and poor in 20% of patients — an overall satisfactory (excellent/good/fair) outcome in 80% (Figure 4).

Table 5. Mobilisation and physiotherapy compliance at final follow-up (n = 20)

Variable	Category	n	%
Weight-bearing at 6 weeks	Full	12	60.0
	Partial	3	15.0
	None	5	25.0
Physiotherapy compliance	Good	11	55.0
	Moderate	6	30.0
	Poor	3	15.0

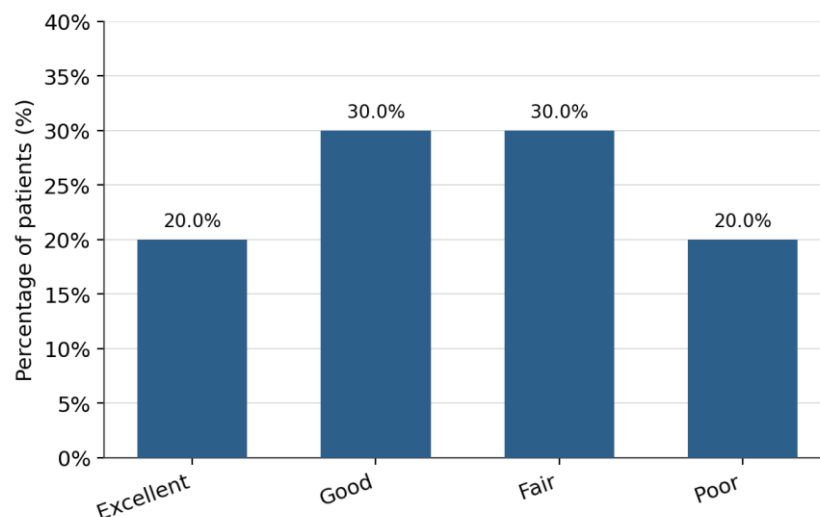


Figure 4. Functional outcome by the modified Ketenjian and Shelton criteria (n = 20)

The mean Injury Severity Score was 16.25 ± 3.52 and the mean time to surgery was 12.30 ± 5.59 hours. The mean time to

radiological union was 23.30 ± 3.64 weeks. The mean Puno functional score (of a maximum 30) was 15.55 ± 3.93 (Table 6).

Table 6. Descriptive statistics of key clinical and functional variables (n = 20)

Variable	Mean $\pm$ SD
Age (years)	40.30 $\pm$ 8.57
Injury Severity Score	16.25 $\pm$ 3.52
Time to soft tissue cover (hours)	47.45 $\pm$ 12.58
Time to surgery (hours)	12.30 $\pm$ 5.59
Time to radiological union (weeks)	23.30 $\pm$ 3.64
Pain score	2.60 $\pm$ 1.67
Range of motion score	2.45 $\pm$ 1.79
Strength score	2.55 $\pm$ 1.54
Residual deformity score	2.95 $\pm$ 2.01
Activities of daily living score	2.75 $\pm$ 1.65
Sensation score	2.25 $\pm$ 1.94
Puno functional score (/30)	15.55 $\pm$ 3.93

On comparison across Gustilo-Anderson grades, Grade II fractures showed the shortest mean time to union (20.40 $\pm$ 2.61 weeks) and the best activities-of-daily-living scores (3.60 $\pm$ 1.67), while Grade IIIC fractures showed the lowest

Puno functional score (12.67 $\pm$ 3.79) despite the shortest flap timing (33.67 $\pm$ 7.37 hours), reflecting greater intrinsic injury severity in this subgroup, yet none showed a statistical significance (Table 7).

Table 7. Clinical and functional profile across Gustilo-Anderson classifications

Variable	Grade II (n=5)	Grade IIIA (n=7)	Grade IIIB (n=5)	Grade IIIC (n=3)	p-value by Kruskal Wallis test
Age (years)	45.60 $\pm$ 3.05	38.71 $\pm$ 9.11	38.20 $\pm$ 10.28	38.67 $\pm$ 11.15	0.496
Injury Severity Score	15.60 $\pm$ 2.70	15.71 $\pm$ 4.07	17.60 $\pm$ 4.04	16.33 $\pm$ 3.79	0.812
Flap timing (h)	54.40 $\pm$ 9.37	49.86 $\pm$ 12.08	45.40 $\pm$ 14.12	33.67 $\pm$ 7.37	0.130
Time to union (weeks)	20.40 $\pm$ 2.61	24.29 $\pm$ 3.59	24.40 $\pm$ 2.97	24.00 $\pm$ 5.29	0.244
Puno functional score (/30)	16.40 $\pm$ 4.28	15.43 $\pm$ 3.31	16.60 $\pm$ 4.77	12.67 $\pm$ 3.79	0.564

Discussion

This prospective study of 20 patients with Gustilo-Anderson Type II, IIIA, and IIIB tibial fractures managed using the fix and flap approach demonstrated satisfactory anatomical and functional outcomes with an acceptable complication profile. Although the present study did not include a comparison group, the findings suggest that single-stage fixation with early soft tissue reconstruction is a feasible management strategy for appropriately selected patients and are consistent with outcomes reported in previous literature.

The mean time to radiological union in this study was 23.3 weeks, comparable to the 22-week union time reported by Gupta et al. [11] and shorter than the 29.7 weeks reported by Neerumala et al. [12] and the 30.1 weeks reported by Karikalan [13]. Singh et al. reported a longer mean union time of 40.3 weeks, which the authors attributed to the inclusion of Grade IIIC fractures and delays in definitive management [14].

Infection remains a key determinant of functional outcome in open fractures. In this series, no deep infections occurred and only 5% of patients developed superficial infection, notably lower than the 12.1% deep infection rate (with 9% flap failure) reported by Singh et al. [14] and the 7% superficial and 7% deep infection rates reported by Neerumala et al. [12]. Ramasamy reported 16% deep infection and 27% pin-tract infection with a staged fix-and-shift protocol, reflecting the challenges associated with delayed definitive coverage [15]. The comparatively low infection rate observed in this series may be attributable to rigorous debridement, early flap coverage (mean 47.45 hours), and appropriate perioperative

antibiotic administration. However, because this study lacked a comparison group, the specific contribution of the fix and flap protocol to the observed infection rate cannot be determined.

By the modified Ketenjian and Shelton criteria, 80% of patients in this study achieved a satisfactory outcome (20% excellent, 30% good, 30% fair), comparable to the 84.5% satisfactory outcome reported by Neerumala et al. [12] and the 91.67% satisfactory outcome (Tucker's score) reported by Ali et al. [16]. Singh et al. reported a lower rate of 57.5% excellent/good outcomes with a substantial 24.2% poor outcome rate, likely reflecting greater injury severity in their cohort [14]. The predominant use of fasciocutaneous flaps (35% of reconstructions overall) in this series is consistent with the observation by Karikalan that fasciocutaneous flaps effectively cover moderate-sized defects with lower donor-site morbidity than muscle flaps [13].

Complication rates in this study (5% nonunion, 5% delayed union, 10% osteomyelitis) were broadly consistent with, or lower than, published series. Gupta et al. reported 5% deep infection and a single case of delayed union [11]. A systematic review by Myatt et al. reported wide variability across studies, with infection being the most frequently reported complication [17]. Ramasamy reported a considerably higher complication and reoperation burden (approximately 50%) with an external fixator-based approach [15]. Only 10% of patients in this series required reoperation, lower than the reoperation rates reported with staged fixation by Cullen et al. and Ramasamy, in whom infection and construct instability were the principal drivers of further surgery [15,18].

At 6 weeks, 60% of patients in this series were fully weight-bearing, comparable to the trend reported by Ayoub et al., who observed 88.5% full weight-bearing by 10 weeks with intramedullary nailing versus only 41.7% with external fixation [19]. These findings are consistent with previous reports suggesting that stable fixation combined with timely soft tissue coverage may facilitate early mobilisation; however, this relationship cannot be established definitively from the present observational study. Good physiotherapy compliance (55%) in this series was associated with better functional scores, consistent with the observation by Patil et al. that early weight-bearing and structured physiotherapy were associated with excellent outcomes in 80% of their cohort, underscoring rehabilitation as an important, often underemphasised, determinant of final functional recovery [20].

There was no mortality and complete (100%) limb salvage in this series, in contrast to the 37 amputations — many attributable to flap failure, infection, or systemic factors — reported in the systematic review by Myatt et al. [17]. This finding is consistent with the concept that timely definitive management within a coordinated orthoplastic framework may contribute to favourable limb salvage outcomes. However, the observational design of the present study does not permit causal inference regarding the effectiveness of this management strategy.

This study is limited by the absence of a formal sample size estimation and a relatively small sample size ($n = 20$), single-centre design, and relatively short follow-up (6 months), which preclude firm conclusions on long-term union and functional recovery, particularly in Grade IIIC injuries. Convenience sampling may

have introduced selection bias, as the enrolled patients may not fully represent the broader population limiting the generalisability of the study results. The absence of a comparison or control group precludes direct assessment of the superiority of the single stage “fix and flap” approach over conventional staged management. Larger, multicentric, and longer-term prospective studies are warranted to confirm these findings.

Conclusion

In this prospective study of 20 patients with open tibial fractures managed by single-stage fix and flap reconstruction, Grade IIIA injuries were the most common presentation, and fasciocutaneous flaps were the most frequently used method of soft tissue cover. The mean time to union across all grades was 23.30 weeks, with a low overall complication rate (45%), a 10% reoperation rate, and complete limb salvage with no mortality. Functional outcome by the modified Ketenjian and Shelton criteria was satisfactory in 80% of patients. Grade II fractures demonstrated the most favourable clinical and functional profile, whereas Grade IIIC fractures were associated with greater complication and reoperation risk and poorer functional scores, indicating that fracture severity remains an important determinant of recovery. Early soft tissue coverage combined with good physiotherapy compliance was associated with favourable functional recovery in this cohort. These findings suggest that single-stage fix and flap management is a feasible treatment strategy for selected patients with severe open tibial fractures; however, comparative studies are required to establish its effectiveness relative to other treatment approaches.

Clinical Implications

The findings of this study suggest that achieving definitive soft tissue coverage within the early post-injury period is feasible in most patients with Gustilo-Anderson Grade II and III open tibial fractures managed in a tertiary care setting. The favourable limb salvage rate and satisfactory functional outcomes observed in this cohort highlight the importance of prioritizing early definitive management and may assist clinicians in counselling patients regarding expected recovery following single-stage reconstruction.

Authors' Contributions

HVM has contributed to the conceptualization, design of the study and manuscript review. TT contributed towards design of the study, literature search and manuscript review. SC has contributed towards data acquisition, statistical analysis, Manuscript writing and editing. SC acted as the corresponding author for this manuscript

Conflicts of interest

The authors declare that they do not have conflict of interest.

Funding

No funding was received for conducting this study.

Ethical Approval

The study was approved by the Institutional Ethics Committee of Dhanalakshmi Srinivasan Medical College and Hospital, Perambalur. (IECHS/IRCHSNo.638/Dt:09.12.2024) Written informed consent was obtained from all participants.

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