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Functional outcomes of a perforator-based bipedicled flap for reconstruction of post-traumatic anteromedial leg defects: a prospective study of 76 patients

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ABSTRACT

Background: Reconstruction of post-traumatic soft tissue defects over the anteromedial leg is challenging owing to the subcutaneous position of tibia, sparse local muscle coverage, tenuous skin vascularity. Conventional options: local fasciocutaneous flaps and microsurgical free tissue transfer are effective, but associated with technical complexity, donor site morbidity and significant resource requirements. This study prospectively evaluates the outcomes of perforator-based-bipedicled-flap technique as a reliable primary reconstructive option.
Methods: A prospective-observational-study was conducted at a single tertiary-care centre between January 2023 and January 2026. 76 patients with open tibial fractures (Gustilo-Anderson types IIIA/IIIB) and associated anteromedial soft tissue defects underwent perforator-based-bipedicled-flap-reconstruction. Posterior tibial artery perforators were directly visualised and preserved during flap elevation. Primary outcome-complete flap survival; secondary outcomes included complication rates, donor site morbidity, functional status at 12 months follow-up.
Results: The cohort comprised 70 males (92.1%) and 6 females (7.9%), predominantly in 30-50-year age group. Defects were frequently located in middle-third of the leg (56.6%). Mean defect dimensions were 3×4 cm. Complete flap survival was achieved in 73 cases (96.1%). Complications occurred in 3 patients (3.9%): 2 cases of wound edge necrosis managed with secondary skin-grafting, 1case of progressive limb ischaemia necessitating above-knee-amputation. No functional deficit attributable to the reconstruction was documented at final follow-up. Donor site morbidity was minimal.
Conclusions: The perforator-based bipedicled flap provides a technically straightforward, reproducible, cost-effective reconstructive solution for anteromedial leg defects following high-energy tibial fractures. Its favourable survival rate, low complication, inherent intraoperative convertibility makes it a valuable primary option, particularly in resource-constrained settings.

Keywords: Bipedicled flap, Anteromedial leg defect, Perforator-based flap, Open tibial fracture, Lower-limb trauma

INTRODUCTION

Soft tissue reconstruction over the anteromedial aspect of the leg following open tibial fractures remains one of the most formidable challenges in reconstructive orthopaedic and plastic surgery. The subcutaneous position of the tibia in this region, combined with the relative paucity of local muscle bulk and the tenuous blood supply of the overlying skin, renders wound closure precarious and renders flap ischaemia a common postoperative concern.[1,2]

Open tibial fractures classified as Gustilo–Anderson types IIIA and IIIB are frequently associated with significant skin and soft tissue loss, necessitating reliable coverage of

exposed cortical bone, periosteum, or fixation hardware.[5] Failure to achieve durable wound closure in a timely fashion is well established to predispose to deep wound infection, chronic osteomyelitis, fracture non-union, and ultimately limb loss. The reconstructive goals are therefore to provide robust coverage, minimise donor site morbidity, maintain distal vascularity, and facilitate early functional rehabilitation.

Bipedicled skin flaps, first described for abdominal wall repair, was subsequently adapted for lower limb defect coverage.[3] In their original form, these flaps depended entirely upon dermal plexus perfusion and were constrained by unfavourable length-to-breadth ratios, which predisposed to distal ischaemia and partial necrosis. Their use consequently declined with the advent of more reliable local fasciocutaneous flaps, the reverse sural flap, and microsurgical free tissue transfer.[4,5]

Contemporary understanding of perforator anatomy has revived interest in the bipedicled design. By incorporating the deliberate identification and preservation of posterior tibial artery perforators during flap elevation — rather than relying solely on dermal perfusion — the modified technique achieves predictable axial blood supply while retaining the simplicity of a single-stage, non-microsurgical procedure.

A further advantage of the present technique is its intraoperative versatility: should perforator anatomy prove insufficient during elevation, the incision may be reconfigured as a propeller flap using the same skin island, thereby providing a built-in surgical salvage option without additional donor site morbidity.

The present prospective study was conducted to evaluate the functional and cosmetic outcomes of this perforator-based bipedicled flap technique in patients with post-traumatic anteromedial leg defects, with the aim of defining its role within the reconstructive ladder for open tibial fractures.

METHODS

Study design and setting

This was a prospective single-centre observational study conducted between January 2023 and January 2026 at the Department of Orthopaedics, Sapthagiri Institute of Medical Sciences and Research Centre, Bangalore, India. Seventy-six consecutive patients who underwent perforator-based bipedicled flap reconstruction for anteromedial leg defects following tibial fractures were enrolled.

Ethical clearance was obtained from the Institutional Ethics Committee prior to study commencement (Ref. No.: SIMSRC/IEC/2013/01), and all participants provided written informed consent. The study was conducted in accordance with the principles of the Declaration of Helsinki (revised 2013).

Inclusion and exclusion criteria

Inclusion criteria

Patients of age >18 years; open fracture of the tibia with associated anteromedial skin and soft tissue loss; defect confined to the anteromedial leg with adequate adjacent soft tissue for bipedicled flap elevation; clinically palpable dorsalis pedis and posterior tibial artery pulses bilaterally; and willingness to undergo surgery and comply with follow-up requirements were included.

Exclusion criteria

Patients with extensive degloving injury with disruption of perforator anatomy; large segmental bone defects necessitating bone transport or grafting; significant deep dead space or cavitary wounds precluding surface flap coverage; peripheral arterial disease or absent distal pulses; and systemic comorbidities constituting anaesthetic contraindication were excluded.

Preoperative assessment

All patients underwent structured preoperative assessment encompassing wound dimensions, depth, and extent of contamination. Distal vascularity was confirmed by clinical palpation of the dorsalis pedis and posterior tibial pulses; formal duplex Doppler ultrasonography was not performed routinely. Open fractures were classified according to the Gustilo–Anderson system. Skeletal stabilisation was achieved primarily by external fixation, following which soft tissue reconstruction was performed within 5–10 days of injury where the wound condition permitted.

Surgical technique

Under general or spinal anaesthesia with tourniquet control, thorough wound debridement and irrigation with normal saline were performed. A longitudinal skin incision was made parallel and posterior to the defect margin. The bipedicled flap was designed with a minimum width of 5 cm and a length exceeding the measured defect by 2–3 cm to facilitate tension-free inset. Flap elevation proceeded in the subfascial plane under loupe magnification (×2.5), with meticulous identification and preservation of posterior tibial artery perforators. Where flap mobility was insufficient for defect coverage, circumferential dissection was extended along the posterior tibial vascular axis to permit further advancement. The flap was transposed anteriorly over the defect and secured with interrupted absorbable sutures. The resultant donor area was resurfaced with a split-thickness skin graft harvested from the ipsilateral thigh.

In the event that intraoperative assessment identified inadequate perforator anatomy, the flap was converted to a propeller flap configuration utilising the identical skin incision, without incurring additional donor site sacrifice. Postoperatively, the limb was immobilised in a well-padded below-knee plaster of Paris slab for one week. Passive range-of-motion exercises commenced at two weeks, with gradual weight-bearing initiated thereafter, contingent upon fracture stability and flap viability.

Outcome assessment

Follow-up was scheduled at two weeks, six weeks, three months, six months, and twelve months. The primary outcome was complete flap survival, defined as full wound closure without requirement for secondary reconstructive intervention. Secondary outcomes comprised partial flap loss (wound edge necrosis managed with skin grafting but without flap re-elevation), total flap loss (necessitating major salvage procedure), infection requiring operative debridement, donor site morbidity, limb functional status, and amputation rate. Data were recorded prospectively on standardised case record forms and analysed using descriptive statistics (frequencies, proportions, and ranges).

RESULTS

Demographic and clinical characteristics

Seventy-six consecutive patients underwent 76 perforator-based bipedicled flap procedures during the eight-year study period. The cohort was predominantly male (n=70; 92.1%), with six female patients (7.9%), reflecting the established male predominance in high-energy lower limb trauma. The most frequent age group was 30–50 years. Road traffic accidents constituted the principal mechanism of injury. Demographic and clinical data are summarised in Table 1.

Table 1: Demographic and clinical characteristics of the study population (n=76).

Parameter	Value
Total patients	76
Sex - male	70 (92.1%)
Sex - female	6 (7.9%)
Age group (years)	30–50 (most frequent range)
Predominant mechanism of injury	Road traffic accident

Defect characteristics

Defects were most frequently located in the middle third of the leg (n=43; 56.6%), followed by the distal third (n=16; 21.1%) and the proximal third (n=9; 11.8%). The mean defect dimensions were 3 cm in width and 4 cm in length. Exposed tibial cortex, periosteum, or metallic fixation hardware was present in the majority of cases, constituting critical defects with a high risk of osteomyelitis without reliable soft tissue coverage. The distribution of defect locations is presented in Table 2.

Table 2: Distribution of defect location by leg third (n=76).

Location of defect	No. of patients (n=76)	Percentage (%)
Proximal third	9	11.8
Middle third	43	56.6
Distal third	16	21.1
Total	68*	89.5

*Eight patients (10.5%) had defects spanning more than one third of the leg and were recorded within the predominantly involved segment

Surgical outcomes

Complete flap survival was achieved in 73 of 76 cases (96.1%). Three patients (3.9%) experienced postoperative complications. Two patients developed wound edge necrosis attributed to increased tension at the flap margin; both were managed successfully with local wound care and split-thickness skin grafting, without requiring flap re-elevation. One patient developed progressive ischaemia of the distal limb in the immediate postoperative period; the aetiology was determined to be pre-existing microvascular disease undetected preoperatively. In light of the patient's refusal of further reconstructive intervention, an above-knee amputation was performed. No additional cases of deep surgical site infection, clinically significant wound dehiscence, or haematoma were recorded. Length of hospital stay ranged from 6 to 21 days, with prolongation attributable to comorbidity optimisation and management of postoperative complications. Outcomes are detailed in Table 3.

Table 3: Surgical and clinical outcomes (n=76).

Outcome parameter	Value
Total flap survival (complete)	73/76 (96.1%)
Partial flap loss - managed with grafting	2/76 (2.6%)
Total flap loss - above-knee amputation	1/76 (1.3%)
Overall complication rate	3/76 (3.9%)
Hospital stay (days)	6–21
Mean follow-up (months)	12 (range 6–24)

Follow-up and functional outcomes

Follow-up duration ranged from 6 to 24 months, with a mean of 12 months (complete follow-up data available for 50 of 76 patients; 26 patients were lost to follow-up). Among patients attending their 12-month review, no clinically evident functional deficit attributable to the reconstruction was recorded, and no vascular compromise of the reconstructed limb was documented. Donor site

assessment revealed well-healed linear posterior leg scars with satisfactory colour and texture match to the adjacent native skin. No patient reported significant functional limitation referable to the donor site. Representative clinical photographs demonstrating flap design, elevation, inset, and 12-month follow-up appearance are provided in Figures 1 and 2.

DISCUSSION

The anteromedial leg represents one of the most demanding anatomical territories for soft tissue reconstruction following high-energy trauma. The present prospective study of 76 patients demonstrates that a perforator-based bipedicled flap technique achieves complete flap survival in 96.1% of cases, with an overall complication rate of 3.9%. These figures support the reliability of this approach as a primary reconstructive modality and compare favourably with both contemporaneous bipedicled flap data and published outcomes for the principal alternatives.

Comparison with published bipedicled flap study is presented in Table 4. Schwabegger et al reported approximately 95% survival in 12 cases, attributing their outcomes to careful attention to flap dimensions.[4] Granzow et al observed success rates approaching 98% and specifically highlighted perforator preservation as the critical technical determinant — a conclusion fully corroborated by our experience.[6] The anatomical basis for these findings was established by the landmark contributions of Pontén, who demonstrated the superior reliability of fasciocutaneous over random-pattern flaps, and by Cormack and Lamberty, whose systematic analysis of perforator territories provides the vascular rationale for including identified perforators within the flap design.[7,8]

Table 4: Comparison of present study with selected published data on bipedicled and free flap reconstruction.

Study	N	Survival (%)	Key observation
Present study	76	96.1	Perforator preservation; intraoperative convertibility
Schwabegger et al[4]	12	~95	Adequate flap dimensions critical to survival
Granzow et al[6]	NR	~98	Perforator-based design improves outcomes
Khouri and Shaw[13]	304	95–98	Free flap; high resource demand and operative time

The predominance of middle-third defects (56.6%) in our cohort is consistent with the anatomical and mechanistic patterns described by Mathes and Nahai, who observed that the mid shaft tibia, as the most exposed bony prominence of the lower leg, is disproportionately involved in direct-impact trauma.[9] The mid-leg also harbours a higher density of posterior tibial artery perforators compared with the distal third, making it the region most amenable to perforator-based local flap coverage without requiring microsurgical augmentation. The male predominance (92.1%) is consistent with the demographic profile of road-traffic-related orthopaedic trauma described by Court-Brown et al.[10]

In comparison with conventional local fasciocutaneous and neurocutaneous flaps, the bipedicled technique offers several practical advantages. Masquelet et al and Kneser et al demonstrated that reverse sural and neurocutaneous flaps, while reliable, frequently yield bulky pedicles with suboptimal contour and may restrict ankle mobility.[11,12] The bipedicled flap, harvested from immediately adjacent tissue, produces a thin, geometrically matched reconstruction with superior colour and texture concordance, minimising the step-off deformity common with transposed neurocutaneous flaps. Furthermore, the posterior donor site scar is well concealed and functionally inconsequential.

When benchmarked against microsurgical free tissue transfer — the established gold standard for complex lower extremity defects — the bipedicled flap is substantially simpler, avoids the requirement for microsurgical expertise and specialised infrastructure, and is feasible under regional anaesthesia. Khouri and Shaw reported 95–98% free flap survival in a large series but identified extended operative time, intensive monitoring requirements, and institutional cost as significant drawbacks.[13] Hallock further noted that the principal risk of free tissue transfer — catastrophic total flap loss secondary to microvascular thrombosis — carries irreversible consequences in a limb already compromised by high-energy trauma.[14] The bipedicled flap eliminates this risk profile while still achieving comparable survival rates in appropriately selected patients.

A technically distinctive advantage of the present approach is its intraoperative convertibility. When perforator anatomy is found to be suboptimal at the time of flap elevation, the identical incision and skin island can be repositioned as a propeller flap, thereby providing reliable coverage without additional incisions or change in donor territory. This inherent flexibility reduces the rate of intraoperative abandonment and second-stage reconstruction, both of which impose significant additional morbidity and cost.

The present study has several limitations that must be acknowledged. First, perforator mapping was performed solely by clinical assessment; routine preoperative duplex Doppler ultrasonography or computed tomographic angiography would provide more objective identification of suitable perforators and potentially refine patient selection. Second, 26 of 76 patients (34.2%) were lost to follow-up at 12 months, introducing a potential attrition

bias that may affect the completeness of functional outcome data. Third, functional recovery was assessed clinically rather than through a validated patient-reported outcome instrument such as the lower extremity functional scale (LEFS) or the short musculoskeletal function assessment (SMFA); future studies should incorporate these tools to enable standardised inter-study comparisons. Fourth, the technique is contraindicated in extensive degloving injuries, wherein disruption of the subcutaneous perforator network precludes safe flap elevation. These limitations notwithstanding, the consistency of outcomes across a relatively large single-centre cohort over an eight-year period lends credibility to the reported results.

CONCLUSION

The perforator-based bipedicled flap is a technically straightforward, reproducible, and cost-effective reconstructive option for post-traumatic anteromedial leg defects in patients with open tibial fractures. Direct visualisation and preservation of posterior tibial artery perforators during flap elevation reliably augments axial vascularity, achieving a complete flap survival rate of 96.1% with minimal donor site morbidity. The technique compares favourably with both local fasciocutaneous flaps and free tissue transfer and is particularly well suited to resource-limited settings where microsurgical infrastructure is unavailable.

Its intraoperative convertibility to a propeller flap configuration using the same skin island provides an effective surgical safety net, further enhancing its clinical value. The authors recommend the perforator-based bipedicled flap as a primary reconstructive choice for anteromedial leg defects, particularly in the middle third of the leg, and advocate its formal incorporation into evidence-based reconstructive algorithms for open tibial fracture management. Prospective randomised controlled trials comparing this technique with propeller flap and reverse sural flap reconstruction are warranted to consolidate its evidence base.

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