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Functional and Aesthetic Outcome of Reconstruction of Leg and Foot Defects: A Comparative Study of Conventional and Microvascular Free Flaps.

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Abstract

Background: High-energy trauma to the leg and foot frequently produces complex soft-tissue defects that threaten limb salvage. Reconstruction has evolved from amputation toward a structured ladder of local fasciocutaneous and muscle flaps and, where defects are large or vital structures are exposed, microvascular free tissue transfer. Comparative data on the functional and aesthetic performance of these two approaches remain limited, particularly from resource-constrained tertiary trauma centres. ***Aim:*** To analyse the sites of leg and foot defects, the age and sex distribution of affected patients, the conventional and microvascular techniques used for reconstruction, the functional and aesthetic outcomes of both methods, and the associated complications. ***Material and Methods:*** This prospective observational study was conducted in the Department of Plastic Surgery, Government Stanley Medical College Hospital, between September 2010 and August 2012. All patients presenting with traumatic soft-tissue defects of the leg and foot requiring conventional or microvascular free-flap reconstruction were included; injuries with bone, tendon, or nerve loss needing composite reconstruction were excluded. Patients were assessed for gait, range of ankle and foot movement, donor-site morbidity, plantar sensation, aesthesis (colour, texture, contour), and duration to return to work. ***Results:*** Sixty-four flaps were performed in 64 patients (45 conventional, 19 free). Conventional flaps predominated for defects under 5 cm, especially fasciocutaneous flaps (24%) and the reverse sural artery flap (20%); free anterolateral thigh flaps accounted for 74% of free flaps and were preferred for defects exceeding 5 cm with bone or vital-structure exposure. Local flaps gave excellent plantar sensation, colour match, and contour, with earlier return to work (4–6 weeks) than free flaps (8 weeks). Total flap loss occurred in 3 of 64 cases (4.7%), and distal partial necrosis occurred in 5 anterolateral thigh flaps. ***Conclusion:*** Local flaps remain the mainstay for smaller leg and foot defects, offering superior sensory and aesthetic outcomes with shorter recovery, while microvascular free flaps are indispensable for larger defects with exposed vital structures, particularly in younger and paediatric patients.

Keywords: Leg reconstruction; Foot reconstruction; Free flap; Fasciocutaneous flap & Limb salvage.

INTRODUCTION

High-energy lower-extremity trauma with extensive soft-tissue injury and associated multiple bony injuries remains a formidable problem in management, and the difficulty is compounded when such injuries occur in the context of polytrauma. [1] Pedestrian motor-vehicle accidents, falls from height, and sporting injuries commonly result in open tibial fractures that demand complex, combined bone and soft-tissue management. Over the past two decades the management of lower-extremity trauma has evolved to the point that many limbs once destined for amputation are now routinely salvaged, a shift made possible by a coordinated team approach involving orthopaedic, vascular, and plastic surgeons.

The history of lower-extremity reconstruction before the First World War was essentially the history of amputation, beginning with Hippocrates' description of amputation as a last resort for ischaemic gangrene and progressing through Celsus's rules of wound management and Ambroise Paré's refinements of amputation technique. John Hunter restricted primary amputation to severe injuries, while Desault introduced the concept of debridement and Ollier popularised immobilisation with plaster casts. The aseptic principles described by Lister reduced wound complications in lower-limb trauma, and improvements in casualty evacuation, shock management, blood transfusion, and antibiotics lowered wound-related mortality from 8% in the First World War to 4.5% in the Second. In the 1960s plastic surgeons began transferring

regional flaps for soft-tissue coverage, and the advent of microsurgery in the 1970s, followed by the introduction of negative-pressure wound therapy in the 1990s, further transformed the reconstructive options available for traumatic lower-extremity injuries.[2]

Fracture management has benefited from improved techniques of external fixation, intramedullary rodding, internal plating, and bone grafting, while soft-tissue management now spans skin grafts, local muscle flaps, fasciocutaneous flaps, and microvascular free flaps. The goal of treating open tibial fractures and pursuing lower-extremity salvage is to preserve a limb that will be more functional than an amputation stump, and patients must be counselled about the anticipated course and functional outcome before reconstruction is undertaken.

Most authors agree that early soft-tissue cover lowers complication rates: Byrd et al. found that the overall complication rate for wounds closed within the first week was 18%, compared with 50% for wounds closed during the subacute phase of one to six weeks.[4] Godina's landmark review similarly demonstrated that wounds closed within 72 hours of injury achieved the lowest complication rate and the highest flap success rate.[5]

In contrast, Yaremchuk et al. argued that the adequacy of serial debridement is a more important determinant of outcome than the precise timing of soft-tissue coverage.[6] Nerve repair and grafting in the lower extremity continue to yield disappointing results; Trumble and Vanderhooft reported only an 11% average return of strength and protective sensation among nine patients, most of whom were in the paediatric age group.[7] Despite this body of literature, comparative data on the long-term functional and aesthetic performance of conventional versus microvascular free-flap reconstruction—particularly with respect to gait, plantar sensation, donor-site morbidity, and aesthesis—remain limited in the Indian tertiary-care setting. This study was undertaken to address this gap by analysing a consecutive series of leg and foot reconstructions performed at a single trauma centre.

Aim and Objectives

- To analyse the various sites of leg and foot defects.
- To study the age and sex distribution of patients undergoing reconstruction.
- To study the various types of flaps performed under each category of conventional and microvascular technique.
- To analyse the functional outcome and aesthesis of reconstruction achieved by the two methods.
- To study the complications associated with each method of reconstruction.

MATERIALS AND METHODS

Study Design and Setting

This was a prospective observational study conducted in the Department of Plastic Surgery, Government Stanley Medical College Hospital, over a two-year period from September 2010 to August 2012. Patients were referred from the departments of orthopaedics and general surgery, or presented directly to the plastic surgery department.

Inclusion and Exclusion Criteria

All patients presenting with traumatic soft-tissue defects of the leg and foot who underwent reconstruction using conventional or microvascular free-flap techniques were included in the study. Injuries to the leg and foot associated with bone, tendon, or nerve loss requiring composite reconstruction were excluded.

Evaluation Protocol

Each patient was evaluated for the nature of injury, age and sex distribution, site of defect, and relevant investigations, and a treatment plan was formulated accordingly. Initial assessment in cases of high-energy injury prioritised exclusion of life-threatening associated injuries; once the patient was stable, vascular status was assessed by pulses, temperature, colour, and turgor of the foot, bony injury was evaluated radiographically, and soft-tissue viability was assessed by serial examination of skin, subcutaneous tissue, muscle, and periosteum, with serial debridement performed as needed. Open tibial fractures were classified according to the Gustilo system

Gustilo classification of open tibial fractures

Type	Description
I	Open fracture with a wound < 1 cm
II	Open fracture with a wound > 1 cm without extensive soft-tissue damage
III	Open fracture with extensive soft-tissue damage
IIIA	Type III with adequate soft-tissue coverage
IIIB	Type III with soft-tissue loss, periosteal stripping, and bone exposure
IIIC	Type III with arterial injury requiring repair

The decision to salvage the limb was based on vascular, bony, soft-tissue, and neurological assessment, after which the reconstructive ladder was applied: progressing from simpler options such as primary closure and skin grafting to local fasciocutaneous and muscle flaps, and, where these lower rungs were unsuitable for the size or complexity of the defect, escalating directly to microvascular free tissue transfer (the reconstructive elevator concept). On follow-up, patients were assessed for functional outcome by gait analysis, range of movement at the ankle and foot joints, plantar sensibility, and donor-site morbidity. Aesthesis was graded by colour match of the flap to adjacent skin, texture match with the surrounding skin surface, and contour suitability for the size of the defect, using a semi-quantitative scale (poor +, good ++, excellent +++). The duration of time to return to work was recorded for both leg and foot defects, for each reconstructive method.

RESULTS

A total of 64 patients with traumatic leg and foot defects underwent reconstruction during the two-year study period, of whom 45 (70.3%) were reconstructed using conventional flaps and 19 (29.7%) using microvascular free flaps.

Table 1: Type and frequency of reconstructive flaps used for leg and foot defects (n = 64)

Flap type	No. of cases	percentage
Conventional flaps (n = 45)		
Fasciocutaneous flap	11	17.2%
Reverse sural artery flap	9	14.1%
Soleus muscle flap	7	10.9%
Gastrocnemius muscle flap	5	7.8%
Cross-leg flap	5	7.8%
Medial plantar flap	3	4.7%
Peroneus brevis muscle flap	2	3.1%
Abductor hallucis muscle flap	2	3.1%
Lateral calcaneal artery flap	1	1.6%
Free flaps (n = 19)		
Free anterolateral thigh flap	14	21.9%
Free temporoparietal fascial flap	2	3.1%
Free latissimus dorsi muscle flap	2	3.1%
Free gracilis muscle flap	1	1.6%
Total	**64**	**100%**

The flap distribution analysis revealed that conventional flaps were utilized in 45 cases (70.3% of total procedures), while free flaps accounted for 19 cases (29.7%). Among conventional flaps, the fasciocutaneous flap was most frequently used with 11 cases (17.2%), followed by the reverse sural artery flap in 9 patients (14.1%), soleus muscle flap in 7 patients (10.9%), and both gastrocnemius and cross-leg flaps in 5 patients each (7.8% each). The medial plantar flap was employed in 3 cases (4.7%), while peroneus brevis and abductor hallucis flaps were used in 2 cases each (3.1% each), with the lateral calcaneal artery flap being least common at 1 case (1.6%). In the free flap category, the anterolateral thigh flap dominated with 14 cases (21.9% of total, 73.7% of free flaps), while temporoparietal fascial and latissimus dorsi flaps were each used in 2 cases (3.1% each), and the gracilis flap in only 1 case (1.6%).

Table 2: Anatomical site distribution of leg and foot defects by flap category

Site of defect		Conventional flaps	Free flaps
Leg defects	Upper 1/3	8	0
	Middle 1/3	13	3
	Lower 1/3	16	5
Foot defects	Dorsum	2	9
	Plantar	6	2
Total		45	19

The anatomical distribution analysis revealed that leg defects were more commonly managed with conventional flaps, with 8 cases in the upper third, 13 in the middle third, and 16 in the lower third, while free flaps were used in 3 middle third and 5 lower third defects with none in the upper third. For foot defects, the dorsum showed a clear preference for free flaps with 9 cases compared to only 2 conventional flaps, whereas plantar defects were predominantly managed with conventional flaps in 6 cases versus 2 free flaps. Conventional flaps were most frequently employed for lower third leg defects with 16 cases, followed by middle third leg with 13 cases. Free flaps were most commonly utilized for dorsal foot defects with 9 cases, followed by lower third leg with 5 cases. The overall distribution demonstrates that conventional flaps

were used in 45 cases while free flaps were employed in 19 cases, with the dorsum of the foot being the only site where free flaps outnumbered conventional techniques.

Table 3: Age and sex distribution of patients by flap category

Flap category	Male	Female	Children
Conventional flaps (n=45)	86% (n=36)	12% (n=5)	2% (n=4)
Free flaps (n=19)	69% (n=13)	5% (n=1)	26% (n=5)

Conventional flaps were predominantly used in males with 36 cases (86%), followed by females with 5 cases (12%) and children with 4 cases (2%). In the free flap group, males comprised 13 cases (69%), females 1 case (5%), and children 5 cases (26%). Overall, males dominated across both groups with 49 cases (76.6%), while females accounted for 6 cases (9.4%) and children for 9 cases (14.1%). Children represented a significantly higher proportion in the free flap group (26%) compared to conventional flaps (2%).

Table 4: Functional assessment of reconstructive flaps (gait/stability, plantar sensation, ankle and foot joint movement, donor-area morbidity, duration of return to work)

Flap type	n	Gait/ stability	Sensation (plantar)	Movements (ankle/foot)	Donor-area morbidity	Return to work (leg/foot)
Conventional flaps						
Fasciocutaneous flap	11	+	+	+	–	4 / 6 wk
Reverse sural artery flap	9	+	+	+	++	4 / 6 wk
Soleus muscle flap	7	+	++	+	–	4 / 6 wk
Gastrocnemius muscle flap	5	+	++	+	–	4 / 6 wk
Peroneus brevis muscle flap	2	+	++	+	–	4 / 6 wk
Cross-leg flap	5	+	–	+	–	4 / 6 wk
Abductor hallucis muscle flap	2	+	+++	+	++	6 / 6 wk
Medial plantar flap	3	++	+++	++	–	4 / 6 wk
Lateral calcaneal artery flap	1	++	+++	++	–	4 / 6 wk
Free flaps						
Free anterolateral thigh flap	14	++	++	++	+	8 / 8 wk
Free latissimus dorsi flap	2	++	++	++	–	8 / 8 wk
Free gracilis muscle flap	1	++	++	++	–	8 / 8 wk
Free temporoparietal fascial flap	2	+	++	+++	–	8 / 8 wk

+ poor, ++ good, +++ excellent, – nil/not assessed.

The functional outcomes assessment across all flap types demonstrated that medial plantar flaps and lateral calcaneal artery flaps achieved the best results with excellent plantar sensation (+++) and good gait stability (++), while fasciocutaneous and reverse sural artery flaps showed moderate outcomes with fair gait and sensation ratings. Soleus, gastrocnemius, and peroneus brevis muscle flaps provided good plantar sensation (++) but only fair gait stability, with no significant donor-area morbidity except in reverse sural and abductor hallucis flaps which showed notable donor site issues (++). The cross-leg flap was the only conventional technique that failed to provide plantar sensation, though it maintained fair gait and movement function.

Among free flaps, the temporoparietal fascial flap demonstrated the best ankle and foot movements (+++) with good sensation and gait, while anterolateral thigh, latissimus dorsi, and gracilis flaps all showed comparable good results across gait, sensation, and movement parameters. The return-to-work timeline showed a clear distinction, with most conventional flaps allowing return at 4 weeks for leg defects and 6 weeks for foot defects, whereas all free flaps required a longer recovery period of 8 weeks regardless of defect location. The medial plantar flap uniquely required 6 weeks for leg defects as well, matching the foot recovery timeline, while the cross-leg flap also needed 6 weeks for both locations due to the staged nature of the procedure

Table 5: Aesthetic outcome (colour, texture, contour) by flap type and overall complications

Flap type	n	Colour	Texture	Contour
Conventional flaps				
Fasciocutaneous flap	11	++	++	++
Reverse sural artery flap	9	++	++	++
Soleus muscle flap	7	++	+	++
Gastrocnemius muscle flap	5	+	+	++
Peroneus brevis muscle flap	2	++	+	+
Cross-leg flap	5	++	+	++
Abductor hallucis muscle flap	2	++	+	++
Medial plantar flap	3	+++	+++	++
Lateral calcaneal artery flap	1	++	++	+++
Free flaps				
Free anterolateral thigh flap	14	+	++	–
Free latissimus dorsi flap	2	+	+	+
Free gracilis muscle flap	1	+	+	+
Free temporoparietal fascial flap	2	+	+	+++
Overall complications (n = 64)				
Total flap loss	3 of 64 cases (4.7%)			
Distal partial necrosis	5 of 14 free anterolateral thigh flaps (35.7%); managed by debridement and split-thickness skin graft			
Donor-area morbidity needing secondary SSG	4 patients			
Mean hospital stay	~2 weeks for conventional (excluding cross-leg flap) and free flaps; cross-leg flap required longer, staged hospitalisation (division at 3 weeks)			

+ poor, ++ good, +++ excellent, – not assessed/not applicable. SSG, split-thickness skin graft.

The aesthetic assessment revealed that the medial plantar flap achieved the best overall results with excellent colour match (+++) and texture (+++), followed by the lateral calcaneal artery flap which showed excellent contour (+++) with good colour and texture match. Most conventional flaps including fasciocutaneous, reverse sural, soleus, and cross-leg flaps demonstrated good colour and contour results (++), though texture was generally rated as fair to good (+ to ++). Among free flaps, the temporoparietal fascial flap provided the best contour (+++) but only fair colour and texture, while the anterolateral thigh flap showed the poorest contour outcome with a negative rating (–) despite acceptable colour and texture. Regarding complications, total flap loss occurred in 3 of 64 cases (4.7%), while distal partial necrosis was observed exclusively in 5 of 14 free anterolateral thigh flaps (35.7%), all managed successfully with debridement and split-thickness skin grafting. Donor-area morbidity requiring secondary skin grafting was seen in 4 patients, and the mean hospital stay was approximately 2 weeks for most procedures, though cross-leg flaps required prolonged staged hospitalisation with flap division performed at 3 weeks.

DISCUSSION

This series of 64 patients confirms that, in a busy tertiary trauma centre, conventional flaps remain the workhorse of leg and foot reconstruction, accounting for 70% of all flaps performed, while free flaps are reserved for the minority of defects that are either too large for local tissue or expose vital structures such as bone, tendon, or major vessels. This distribution mirrors the principle articulated by Khouri and Shaw that microvascular free flaps should be considered an extension of, rather than a replacement for, the reconstructive ladder in lower-extremity trauma.[1] The predominance of fasciocutaneous flaps and the reverse sural artery flap in our series for defects under 5 cm is consistent with the well-described reliability of these flaps for the middle and lower thirds of the leg, as originally popularised by Ponten and later refined by El Saadi and Khashaba's three-flap anteromedial fasciocutaneous concept.[10,11]

The timing of soft-tissue coverage has long been recognised as a major determinant of outcome. Byrd et al. demonstrated a marked rise in complication rate from 18% for wounds closed within the first week to 50% for those closed in the subacute phase,[4] and Godina's classic series similarly showed the lowest complication and highest success rates when free-tissue transfer was performed within 72 hours of injury.[5] Our protocol of early debridement followed by either local or free coverage, guided by an assessment of vital-structure exposure, is consistent with this evidence base, although unlike

Yaremchuk et al., who emphasised the adequacy of debridement over the absolute timing of coverage,[6] our data do not permit a direct comparison of these two variables because timing of definitive coverage was not stratified in this analysis. Functionally, local flaps in this series achieved excellent plantar sensation and gait scores, a finding that reflects the preserved sensory innervation of flaps such as the medial plantar flap, which carries the medial plantar nerve and has long been advocated by Shanahan and Gingrass specifically for heel resurfacing because of its glabrous, sensate skin.[15] By contrast, the bulkier free anterolateral thigh flap, while extremely versatile and reliable—as originally described by Song et al. on the basis of the septocutaneous perforators of the descending branch of the lateral circumflex femoral artery[17]—scored only fair for colour and texture match (Table 5) and was associated with difficulty in footwear use, consistent with its known bulk in non-obese Asian populations. This trade-off between reliability of a large, well-vascularised flap and aesthetic/functional refinement is a recurring theme in lower-limb reconstruction and underscores why thinner alternatives such as the free temporoparietal fascial flap, when applicable, were associated with superior contour preservation in our series.

The 4.7% total flap loss rate and the 35.7% partial necrosis rate among anterolateral thigh flaps in this cohort (Table 5) are within the range reported for free tissue transfer to the distal lower extremity, an anatomical region historically associated with higher microvascular failure rates than other recipient sites due to the relatively limited calibre and atherosclerotic predisposition of the posterior tibial and peroneal vessels.[9] The donor-site morbidity observed with several conventional flaps, particularly the reverse sural artery flap and the abductor hallucis flap (Table 4), is consistent with the known trade-off of sacrificing the sural or medial plantar neurovascular pedicle, and reinforces the importance of careful flap selection in patients who depend on intact plantar sensation for safe ambulation.

The age and sex distribution observed (Table 3)—a marked male predominance among conventional flap recipients (86%) contrasted with a substantially higher proportion of children among free flap recipients (26%)—likely reflects two distinct injury patterns: adult male occupational and road-traffic trauma managed expediently with local tissue, versus more severe paediatric crush and degloving injuries in which local tissue is often unavailable or unreliable, necessitating free tissue transfer despite the technical demands of paediatric microsurgery. This pattern is consistent with reports that nerve regeneration and functional recovery after lower-extremity nerve injury, while generally poor, are relatively more favourable in children, as shown by Trumble and Vanderhooft,[7] which may make free flaps with neurorrhaphy a more attractive option in this age group.

Taken together, these findings support a defect-size- and site-driven algorithm: local flaps for defects under 5 cm with adequate surrounding tissue, and free flaps—predominantly the anterolateral thigh flap—for larger defects or those exposing vital structures, with thinner free fascial or muscle-with-graft options preferred over bulky flaps when contour and footwear compatibility are a priority. Limitations of this study include its single-centre design, a relatively short two-year follow-up window that may understate late functional decline, and a semi-quantitative rather than validated functional scoring instrument; future studies using standardised limb-salvage scoring systems and longer follow-up are warranted to confirm these observations.

CONCLUSION

Local flaps are the mainstay of reconstruction for smaller leg and foot defects, providing good functional and aesthetic results with shorter hospital stay and earlier return to work compared with free flaps. For larger defects exposing vital structures, where local flaps are unavailable, free flaps remain the principal reconstructive option, with free temporoparietal fascial and free latissimus dorsi muscle flaps offering better functional and aesthetic outcomes for dorsum foot defects than the bulkier free anterolateral thigh flap. Early wound coverage within one week mitigates infection, shortens hospital stay, and enhances patient productivity, while thinner, sensate flaps achieve earlier bipedal gait and better footwear acceptance than bulky alternatives.

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