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Case Series

# Antero-Lateral Thigh Free Flap: A Reliable Option for Partial and Complete Soft Tissue Reconstruction of the Sole

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**Abstract**

Composite tissue loss of the sole poses a challenge as it requires flaps which provide a smooth gliding surface to tendons and afford durable weight-bearing. The objective of this case series, which includes 8 patients with partial or complete sole defects reconstructed with the free anterolateral thigh flap, is to evaluate the usefulness of the free ALT flap for reconstruction of sole defects in terms of functional and aesthetic outcomes. Flap success was achieved in 7 out of 8 patients (87.5%); postoperative ulceration occurred in 1 case. Microvascular venous revision was required in 3 cases; 2 were salvaged. All patients were able to weight-bear with normal gait. 4 were able to wear a shoe one size larger than the opposite foot. No donor site morbidity was reported. Patient satisfaction was 87%. Our results propose that the free ALT flap is an excellent choice to reconstruct complex defects of the sole.

**Keywords:** Anterolateral thigh flap; Free flap; Sole defects

## Introduction

Foot injuries are common, with road traffic accidents, roll over injuries, and crushing between heavy objects being the most common causative mechanisms. Soft tissue defects in the foot and ankle region also occur secondary to ischemia, infection and oncological excision. The skin on the plantar surface of the foot is under enormous stress even in normal conditions from the distribution of weight and shear forces across it. To counter these forces there exists a thick dermal layer and septo-fibrous subcutaneous fat that firmly adheres to the underlying bones [1]. Because of its weight bearing function, distinctive anatomy, biomechanics, and precarious vascularity of surrounding skin, reconstruction of soft tissue defects of the weight bearing foot poses a challenging task to the reconstructive surgeon [2,3], particularly in light of the frequent development of stress lesions secondary to body weight and shear forces. [4] Three-dimensional defects in the foot resulting from composite tissue loss ideally require flexible and well-perfused flaps, which fill the defect, afford resistance to infections, provide a smooth gliding surface to tendons (which may have been repaired), and afford supple, durable weight- and

pressure [5]. In order to solve this reconstructive dilemma various approaches have been put forward. Revascularization of the plantar surface of the sole after degloving injury has been reported by Graf et al [6] and Jeng et al. [7] Another possibility is to graft the dermis and epidermis of the avulsed skin pad on the ipsilateral calf or thigh in first stage and then transfer it to the foot in a subsequent stage. [8] If the avulsed foot skin is deemed unusable owing to the mechanism of injury or the status of the tissue then reconstruction with a muscle flap with skin graft [5] or a fascio-cutaneous pedicled or free flap is sought. [9] The last option is almost always the case, with the native degloved skin flaps being lost or non-viable.

The Antero-Lateral Thigh Flap (ALTF) was initially described by Song et al in 1984 [10] based on perforators from the descending and/or transverse branches of the lateral circumflex femoral artery [11,12]. Among its advantages are its large skin paddle size, generous pedicle length, good vessel diameter (2-5 mm artery) and allowance for variability in design. In addition, a muscle segment (such as part of the vastus lateralis or Tensor fascia Lata) can be included on the same pedicle, providing additional bulk if required. The flap can be made sensate with harvest of the lateral femoral cutaneous nerve. There is minimal functional and cosmetic donor site morbidity and most of the flap can be raised without committing to a final design; this permits one to start harvesting the flap before the final dimensions of the defect are determined. Thus, the flap is extremely versatile and can cover a wide variety of soft tissue defects [13]. Previous literature has reported some complications with the ALTF, which may be immediate or delayed. Immediate complications include mainly the need for microsurgical revision, and later complications may be donor or recipient site infection, dehiscence, flap necrosis, or the need for debulking. [14,15] The ideal flap for reconstruction of the sole should provide well-vascularized tissue coverage to act as a barrier to infection, be able to resist weight and shear forces, allow for contouring for foot wear, and sometimes elevation or dissection for subsequent orthopedic procedures. Conventional local flaps are limited to small defects, and for larger defects micro vascular reconstruction is required. This article reviews our experience with the Free Anterolateral Thigh (ALT) perforator flap for soft tissue coverage of the sole and proposes it to be a work-horse flap to reconstruct these defects.

## Patients and Methods

In this article we report a total of 8 patients with sole defects, total or partial, for which free Anterolateral Thigh Flaps (ALTF) were performed between September 2017 and December 2022. Patient demographics and detail regarding flap size and microvascular anastomosis is found in Table 1 and Figure 1. Salient outcomes, early and delayed, are noted in Table 2.

| Case # | Age in years /Sex | Primary Lesion | Defect | ALT Flap Dimensions (cm) | Microsurgical Anastomosis | Donor Site Closure |
|---|---|---|---|---|---|---|
| 1 | 22/M | Left Mangled Foot, post RTA | Total | 24x12 | PTA (ETS) +2 VC | STSG |
| 2 | 24/M | Right foot Post AVM excision | Partial | 10 x 10 | DPA (ETS) +1 VC and GSV (ETE) | STSG |
| 3 | 37/M | Right foot Circumferential Degloving post RTA | Total | 22 x 10 | PTA(ETS)+ 1 VC + GSV (ETE) | STSG |
| 4 | 30/M | Mangled Right foot Post RTA | Partial | 30 x 13 | PTA (ETS)+ 1VC +GSV (ETE) | STSG |
| 5 | 7/F | Crush injury, degloving | Partial | 8 x 9 | PTA(ETS)+1 VC + GSV (ETE) | Primarily closed |
| 6 | 11/F | wheel spoke injury, degloving | Partial | 15 x 10 | PTA (ETS) + GSV + tributary of GSV (ETE) | STSG |
| 7 | 34/M | RTA/R plantar degloving | Partial | not documented | PTA (ETS) + 2 VC | STSG |
| 8 | 4/M | RTA/L foot degloving | Partial | not documented | ATA (ETA) + 1 VC + GSV (ETE) | STSG |

PTA: Posterior Tibial artery, DPA: Dorsalis Pedis artery, ETE: end to end, ETS: end to side, VC: Vena commitantes, GSV: Greater saphenous vein ALT: Anterolateral thigh

**Table 1:** Flap and Anastomoses details - all patients.

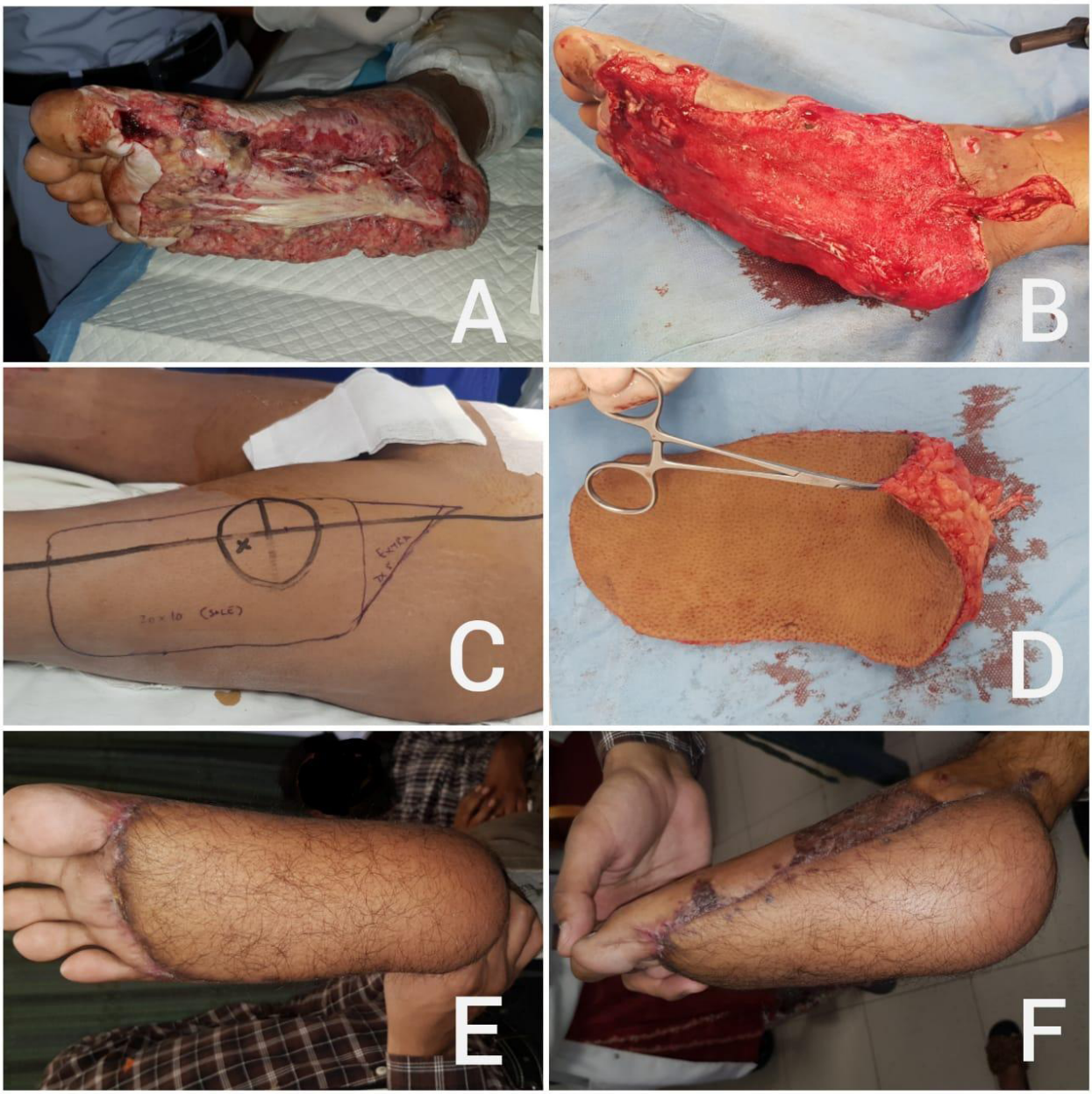


**Figure 1:** Case 1 **A:** Post RTA defect right foot, **B:** Preoperative view of the defect, **C:** Flap dimensions and planning, D: Harvested Flap, E and F: 2 months postoperative view.

| Case No | Early | | | Delayed | | | | |
|---|---|---|---|---|---|---|---|---|
| | Exploration | Management If Explored | Flap Healthy | Weight Bearing | Shoe size (considered "regular" if same size or 1 size greater than unaffected foot) | Ulceration | Donour site morbidity | Aesthetic |
| 1 | No | N/A | Yes | Yes | Regular | None | No | 04-May |
| 2 | NO | N/A | Yes | Yes | Regular | None | No | 05-May |
| 3 | Yes (Congestion due to venous thrombosis) | Revision of Vein anastomosis | Yes | Yes | Regular | None | No | 05-May |
| 4 | No | N/A | Yes | Yes | Regular | Yes (Base of first metatarsal) | No | 04-May |
| 5 | No | N/A | Partially Healthy - ⅓ surface area debrided due to epithelial necrosis and subsequently grafted | Yes | Regular | None | No | 03-May |
| 6 | Yes (Hematoma + wound infection) | Drainage of Hematoma + Pus | Healthy | Yes | Regular | None | No | 04-May |
| 7 | Yes (Venous Congestion) | Revision OF Vein Anastomosis | No - Necrotic flap derided 3 months post op, definitive coverage with STSG + fillet flap from first toe | Yes | Regular | None | No | 02-May |
| 8 | Yes (venous Congestion) | Revision of Vein Anastomosis | Yes | Yes | Regular | None | No | 04-May |

STSG: Split Thickness Skin Graft

**Table 2:** Early and Delayed Outcomes - all cases.

Data was collected retrospectively from the operative, in-patient and outpatient clinical notes available at the hospital's patient record system, HIMS. All patients with a defect of any etiology that extended to the sole of the foot – involving it partially or completely – that had been covered with a free ALTF were included in the study. These amounted to a total of 8 cases.Data regarding post operative recovery, flap survival and early and delayed complications was retrieved from hospital records. All patients were contacted via telephone for a response to the question about satisfaction with aesthetic outcome. All were also asked about their most recent functional status (ability to weight bear, foot wear use) and the appearance of any new plantar lesions which had not been seen in our clinic. If this were the case they were asked to present to clinic in person for evaluation and reviewed. The study was approved by the hospital's Ethical Review Committee. In our practice pre-operative vascular imaging such as CT or MR angiography is not the norm for every case - this was only done for one patient, who also had significant bony trauma to the affected leg. In some cases, the skin paddle was planned around perforators identified with on-table use of a hand held doppler. The flaps were raised and inset in standard fashion. Nerve co-aptation/ neurotisation was not performed in any case. The lateral femoral cutaneous nerve was not harvested with the pedicled in any case. Post-operatively the flaps were monitored for arterial insufficiency and venous congestion via subjective assessment of color, capillary refill, bleeding to pin prick, temperature, and turgor. The patients were kept on a continuous leg elevation protocol for the first week and then intermittent leg elevation for the next week. After this, they were advised to continue daily activities with special emphasis on physiotherapy to prevent joint stiffness. The patients were required to go through an early rehabilitation program, education and serial follow ups.

## Results

We review a series of 8 cases, where the soft tissue defect involved the sole completely or partially. The free Anterolateral Thigh Flap (ALTF) was used for coverage of all defects. All cases were performed by a single experience microvascular surgeon at a tertiary care center in Karachi. 6 out of 8 patients were male; the 2 female patients were both pediatric patients. The most common mechanism of injury was trauma, secondary to road traffic accidents or crush injuries caused by falling objects; one patient acquired the defect after tumor excision (arterio-venous malformation). 6 defects were partial; 2 were complete sole defects.The three arteries at the ankle level and their terminating branches in the foot that can be used as recipient vessels for free flaps include the anterior tibial- dorsalis pedis artery, posterior tibial-medial and lateral plantar arteries, and peroneal-lateral calcaneal artery. The posterior tibial artery was the most commonly used donor vessel for arterial anastomosis, used in 6 patients (75%), as can be seen in Table 1. In one case the dorsalis pedis artery was used, and in one other case the anterior tibial artery was used. All arterial anastomoses were performed end to side, with the exception of one pediatric patient, where an end-to-end anastomosis was performed after ensuring viability of the distal foot once the recipient artery had been reversibly clamped intra-operatively. As is the practice of the operating surgeon, invariably 2 veins were anastomosed each time, always end-to-end, to maximize venous outflow from the flap. All but one patient required split thickness skin grafting for donor site closure. In our series no patient had a known history of vascular risk factors, namely comorbid diabetes mellitus or peripheral vascular disease, apart from the patient with an AVM.The average flap dimensions were 14.3 cm (longer dimension) by 10.3 cm (shorter dimension). The maximum size harvested was 30 x 13 cm (390 cm2). It is of note that this flap survived fully; no portion of the skin paddle underwent necrosis. Where defects extended beyond the sole, small areas on the medial and dorsal side where weight-bearing was not an issue were covered using split-thickness skin grafts. The flap survival rate (flap survival was judged as the presence of any amount of viable flap tissue at the latest follow-up available for each patient) was 87.5%. There was one case of complete flap failure - where the flap was initially re-explored due to venous congestion, both arterial and venous anastomosis revised, and then the flap eventually debulked; it underwent necrosis post the debulking procedure and the index defect was then definitively grafted once there was sufficient granulation over the wound. This patient presented with a mangled extremity and had multiple concomitant orthopedic injuries. In this case the flap was harvested with part of the vastus lateralis. At the site of injury, there was significant bony loss + necrosis of the second and third metatarsals. An ICBG (iliac crest bone graft) was used and k-wired in place. These were later debrided due to chronic infection and a fillet flap (first toe) was used. Overall, four flaps required re-exploration (all during the index hospitalization) after the flaps showed signs of venous congestion, all within 3 days post operatively. In one case, a collection was found under the flap compressing the pedicle, which was drained. Microsurgical revision was not required in this case. At final discharge all patients had a well perfused, adequately inset, non-dehiscent flap. 3 of the 4 had thrombosed veins upon re-exploration-thrombectomy and revision of the venous anastomosis was performed, and the flaps salvaged. At initial discharge all flaps were healthy. At long term follow up 2 underwent partial flap loss and 1 flap (detailed above) underwent complete necrosis.Overall, with the exception of the one flap that was lost completely, 3 other cases underwent some degree of flap loss at follow up.

Two of these were pediatric patients; one of these flaps showed signs of infection with discharge from wound edges, needing multiple debridements and two week-long antibiotic courses, one at short term follow up (within 3 weeks), and another course again

at 4 months post-operatively. However, most of the surface area of the flap was salvaged - only a small portion was found necrotic at repeat debridement at 4 months and excised. The second case showed more flap necrosis, with the distal ⅔ needing surgical excision. The proximal ⅓ had good perfusion and was salvaged. The patient with the AVM underwent flap debulking, following which a small area underwent necrosis and was debrided: this secondary defect was covered with split thickness skin grafting. Flap outcome was assessed at two chronological follow ups – between 3-4 weeks post operatively, and at 2-3 months post operatively, whenever the patient presented within these time ranges. No patient was lost to follow up during this time. 1 patient was operated within 1 month of the writing of this manuscript. We evaluated flap outcomes in three major domains: flap survival, functionality, and cosmesis. We also looked at donor site morbidity. Flap survival has been detailed above. All early and delayed flap outcomes are enlisted in Table 2**.**

We assessed donor site morbidity with the following: the need for re-grafting (due to poor uptake), hypertrophic scar at the donor site, interference with knee joint movement, skin necrosis or dehiscence if primary closure attempted, or any infection of the donor site within 1 month post-operatively. There was no donor site morbidity documented in any case.In terms of function, we assessed, foremost, if patients were able to bear weight normally and use of footwear. At the end of our study all patients were able to bear weight with normal gait (noted subjectively by the authors at the patients' latest follow up visit and as reported by the patients themselves). The most recent long term follow up available between patients ranged from 1 month to 4 years. At 2-3 months follow up the reconstructed foot would accommodate footwear 1 size larger compared to the normal, contralateral foot in 4 patients without any complaints. 3 (37.5%) patients were assessed to have a bulky flap, which hindered footwear accommodation. In 2 of those patients, a flap thinning procedure was performed at around 2 months from the primary surgery in which the excess bulk of the flap was excised, both without complication. The procedure enabled accommodation of footwear 1 size larger than the contralateral foot after 1 month of revision surgery. A debulking procedure is being planned at the time of writing of this manuscript for the third patient. Documentation of formal sensory testing was not available for any patient in our series. The presence or absence of neuropathic ulceration over the flap skin was therefore used as a surrogate indicator of adequate sensory integrity. We collected data on the presence of ulceration (with clinical features characteristic of that secondary to loss of sensation) on the plantar aspect of the reconstructed sole. No patient had any lesion over the flap at 3 months follow up. A year post-operatively, only one patient presented with small areas ulceration at the plantar aspect of the first meta-tarsal base. This patient also had concomitant orthopedic injuries at the time of initial presentation (a distal ⅓ fibula fracture and ipsilateral patellar dislocation), and underwent medial malleolar K wiring and placement of an external fixator (femur) prior to our flap for soft tissue coverage.

Two other patients had a need of simultaneous orthopedic intervention; an 11 year old female patient with an exposed but intact Achilles' tendon, calcaneal fracture and bone loss. K wires were inserted into the calcaneum in the same operative setting as the free flap. They were later removed through the flap without complication. Aesthetic outcome was evaluated in terms of patient report of satisfaction with the obtained cosmesis at least 3 months post operatively, on a Likert scale, with 1 being unsatisfied and the rest being fully satisfied. Pediatric patient report was obtained from the legal guardian. All except 1 patient reported reasonable satisfaction (⅗ or greater) at latest follow up (Figures 2,3).

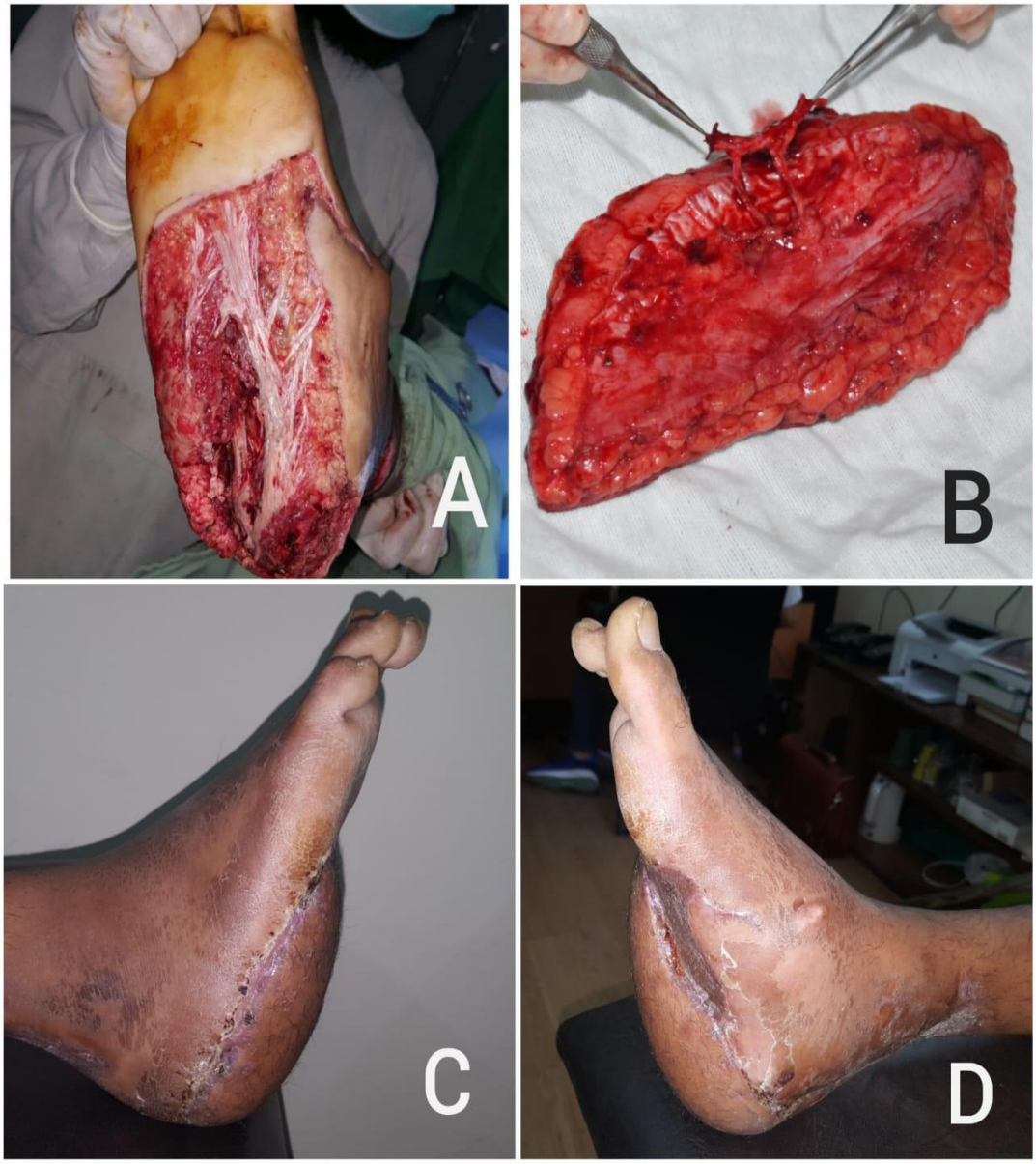


**Figure 2:** Case 2 **A:** Preoperative view of the defect, **B:** Harvested flap, **C and D:** 2 months Postoperative view.

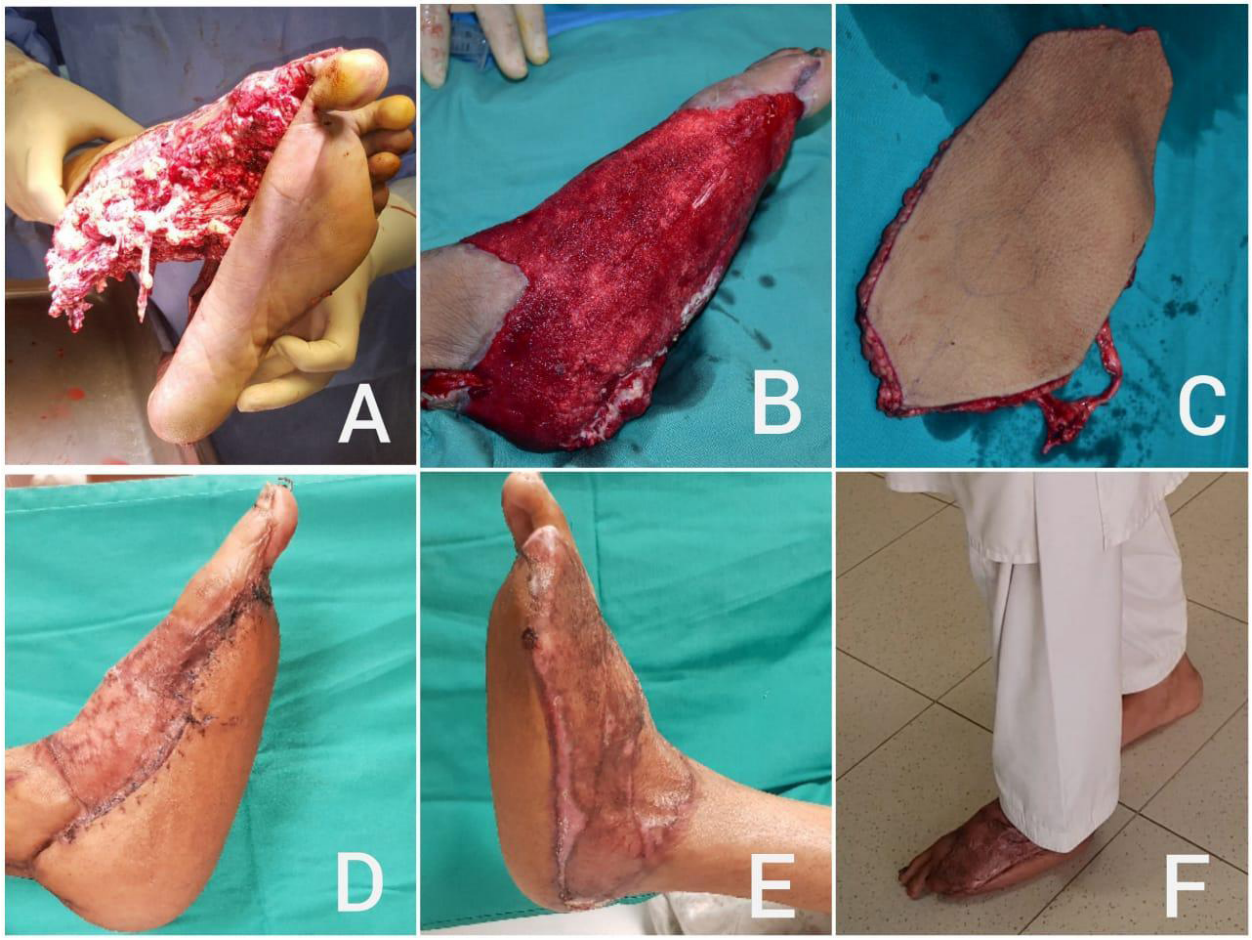


**Figure 3:** Case 3 A: Circumferential Degloving Left Foot , B: Preoperative view of the defect, C: Harvested Flap, D and E : 2 months postoperative view, F: Patient is able to bear weight on the reconstructed sole.

## Discussion

In 2010, Stevenson et al [16] proposed three basic principles for the repair of heel trauma: sensation, stability, and satisfactory appearance. This may be extrapolated to the reconstruction of all plantar defects, heel inclusive. The perfect recipe for sole reconstruction should include provision of a sturdy and pliable weight bearing surface, resistance to shearing forces generated by walking and other activities, and adequate protective sensation. Occasionally, in order to deal with dead space, additional bulk is required which warrants a muscle flap with skin grafting but problems relating to skin grafts such as hyperkeratosis, recurrent ulceration, fissuring and bulkiness remain [17]. Conversely, thin, supple coverage is necessary for adequate joint mobility, normal footwear, and aesthetic acceptability. Ohjimi et al compared conventional flaps and thinning of flaps in lower extremity reconstruction and concluded that the thin flap reduces secondary operations and was superior in functional and aesthetic aspects [18]. Rautio et al concluded that, in foot reconstruction, the optimal thickness of the flap should be less than 6 mm for adequate tightening [19]. The anterolateral thigh perforator flap can be harvested both suprafascially and subfascially based on the thickness required -we have done both in our practice. It can also be safely thinned to 3 to 4 mm except for the pedicle site, thus providing sufficient contour for the daily footwear without laxity or slippage. Flap debulking may be primary (immediate) or secondary (delayed). The authors prefer secondary defatting because it reduces the risk of circulatory insufficiency that is associated with primary thinning. Conversely, the flap may be harvested as a musculocutaneous flap with inclusion of the adjacent muscles such as the vastus lateralis, tensor fascia lata, or rectus femoris to fill significant dead space and to provide cushioning in weight-bearing areas. For the above noted factors we have found that the ALTF ticks almost all boxes

-the authors have harvested the flap with part of vastus lateral is in one case above. 83% of the soft tissue defects we operated on were post-traumatic. Two of these needed concurrent orthopedic intervention, including placement of hardware at the recipient site; the recipient bed was therefore inevitably violated. We found that at least 2 debridement, with the use of interim vacuum dressings, were essential before the recipient site was ready to receive free transferred soft tissue. None of our flaps suffered arterial insufficiency and a few needed venous microsurgical revision- these results are likely due to the good caliber and integrity of the donor pedicle. Both flaps that had concurrent orthopaedic procedures performed proved to have adequate bulk to support and protect orthopedic hardware that was placed under them. Two of our flaps were debulked more than 6 weeks after surgery - the indication was non-cosmetic: the accommodation of foot wear. If needed, thinning procedures are easily done and do not add any significant morbidity to the patient. The authoring surgeon does not routinely neurotize the ALTF; however the lateral femoral cutaneous nerve, encountered superficially during flap dissection, is available for nerve co-aptation at the recipient site if intended. In the authors' experience and from various reports in reconstruction [20], protective sensation is often regained in adequate measure from neural regeneration ("creeping") of adjacent sensory nerves without neurotization [21,22].

We were also able to show this through the lack of any neuropathic ulceration in 7 out of 8 cases to date. Recently, Summa et al were able to show the presence of sensory recovery via formal testing in non-innervated free ALTF flaps, and that smaller harvested surface areas have better recovery. [23] As early as 2002, Santanelli et al showed that a non-innervated fascio-cutaneous flap showed progressive improvement in sensitive thresholds, achieving good protective sensitivity, similar to that of an innervated flap. [24] At times the ALT flap has fallen into disfavor particularly because of the questionable consistency of its vascular anatomy and tedious dissection in case of a musculo-cutaneous perforator. However, Wei et al reported that reliable skin vessels were identified consistently, with the exception of only six of 672 cases [25]. In our experience if a perforator is not found in its usual location or if it is not of good caliber then we may explore more proximally or switch our planned elevation pedicle to the transverse branch of circumflex femoral artery. Similarly we have not found pedicle length, though not objectively documented, to be inadequate in any of our cases. In lower limb and foot plantar defects, close proximity of the recipient vessel to the site of trauma and perivascular scarring may lead to increased vulnerability of vessels and consequently increased chances of anastomotic failure. Therefore, some preoperative assessment of both donor and recipient vessels is sometimes necessary for successful sole reconstruction. We recommend the use of pre-operative hand held doppler in delineating vessel presence, anatomy and integrity before the case is begun. We use pre-operative CT/MR angiography only in selective cases. Our results are similar to other published series where the free ALTF was used to reconstruct plantar defects. A group from China reported a series of 9 cases, where all flap survived completely. Like in our series, the maximum dimensions harvested went up to 30 x 11 cm. They, too, required secondary debulking in a significant number of cases (5 out of 9). They did not perform sensory nerve reconstruction in all their flaps, and none of their flaps developed any ulceration at 12 months follow up. [20] As with any reconstruction, patient education and selection is of important in order to achieve long term success following reconstruction. In order to allow early weight bearing of the reconstructed foot, aggressive physiotherapy and compression dressings /stockings play a vital role in reducing edema and facilitating early molding of the flap – to which the patient must comply. We also need to work in concert with orthopedic and at times vascular colleagues if the nature of the primary lesion necessitates it.

## Conclusion

The anterolateral thigh perforator flap provides a large, pliable skin island and Sufficient bulk, with adjacent muscles if necessary, allowing three-dimensional tailoring to complex defects. The flap itself can be debulked to provide thin, versatile coverage, allowing exceptional contouring of the plantarsurface. It results in minimal donor-site morbidity and allows fast rehabilitation. We suggest that this versatile flap deserves special attention as a reliable option in sole reconstruction. With proper preoperative patient evaluation and standardized postoperative management including education and rehabilitation, flap outcomes functional and aesthetic can be maximised.

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