Sliding advancement medial plantar artery flap for soft-tissue reconstruction of total heel defects without scar over the weight-bearing area: A case series

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Abstract:

Reconstructing total heel soft-tissue defects is complex, but the sensate medial plantar artery flap closely mimics heel anatomy. This retrospective observational study describes four cases: two males and two females, aged 3-52 years. Patients presenting with total heel pad defects underwent reconstruction using a sensate medial plantar artery flap without a scar over the weight-bearing area of the heel from 10/2020 to 02/2024. Follow-up ranged from 12 to 48 months. Flap survival, sensory recovery based on the British Medical Research Council (BMRC) scale, and functional recovery based on the American Orthopaedic Foot and Ankle Society (AOFAS) score were studied. Defect size ranged from 4×6 cm to 10×12 cm. Flap size ranged from 5×6 cm to 9×10 cm. All four flaps survived completely, and the donor sites were successfully covered with split-thickness skin grafts. At follow-up from 12 months to 4 years, all patients had good functional recovery with satisfactory aesthetic results. Ultimately, reconstruction of total heel pad defects with this flap without a scar over the weight-bearing area of the heel achieved satisfactory results, with normal function, minimal donor-site morbidity, and a good aesthetic outcome.

Keywords: **heel pad defects, medial plantar artery, medial plantar artery flap, reconstruction of heel defects, sensate flap.**

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1. Introduction

Total heel soft-tissue defects are often intractable problems in plastic and reconstructive surgery. The causes of these defects include trauma, complications of diabetes mellitus,

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peripheral vascular disease, tumour excision, and burns. The challenges in reconstructing these defects primarily lie in preserving the function, contour, and aesthetic outcome of the heel. When full body weight is transmitted through the foot, the heel bears approximately 80% of body weight [1]. Therefore, the heel pad has unique intrinsic properties that accommodate the high compressive load and shearing forces exerted during standing and ambulation [2]. This structure includes a large fat pad with fibrous septa binding the plantar skin to the plantar aponeurosis, constructing fat loculations that produce a shock-absorbing system and minimise skin laxity. This special skin-aponeurosis system is crucial for the weight-bearing area of the foot. Additionally, the heel region exhibits dense sensory innervation to avoid trauma and ulceration [3]. Therefore, the primary principles guiding heel reconstruction are to provide sensate skin with a similar anatomical structure to maintain weight-bearing function, ankle and foot function, and avoid late flap ulceration [4].

For the reconstruction of total heel pad defects, reverse sural artery flaps and free flaps usually need to be considered because these flaps can be harvested in adequate sizes to cover the defects. However, these options have some obvious disadvantages in terms of their ability to withstand the stress of body weight and provide sensation [5]. The medial plantar artery flap (MPAF), which has many advantages in heel reconstruction, was first introduced by D.H. Harrison, et al. (1981) [6]; the flap was located in the non-weight-bearing area of the plantar foot and supplied by the medial plantar neurovascular bundle. Using this flap for heel reconstruction produces good outcomes, with the ability to withstand body weight and maintain ankle and foot function and protective sensation. However, the traditional technique involves transferring the flap as an island flap, so most scars are located on the weight-bearing area. In this article, we present the results of four cases of total heel pad reconstruction using an advancement medial plantar artery flap with a sliding technique without a scar over the weight-bearing area of the heel and discuss the distinct advantages of this flap.

2. Patients and methods

This was a retrospective observational study of four cases of total heel pad reconstruction with a medial plantar artery flap over a period of 4 years, from October 2020 to February 2024, conducted at the Department of Maxillofacial-Plastic-Aesthetic Surgery, Viet Duc University Hospital. The study was approved by the Institutional Review Board of Viet Duc University Hospital (No. IRB-VN01.021). Follow-up ranged from 12 to 48 months. Follow-up ranged from 12 to 48 months. Patients were examined to determine the size and depth of the defect, as well as any associated calcaneal bone injuries. The condition of the instep area and the posterior tibial and medial plantar arteries was assessed. Photographs were taken preoperatively, intraoperatively, and postoperatively. Outcomes

were assessed at least 12 months postoperatively based on flap viability, ankle-foot function using the AOFAS score, and sensory recovery using the BMRC scale.

Anaesthesia: general anaesthesia or spinal anaesthesia.

Surgical positioning: supine position.

Preoperative planning:

Vascular patency and the course of the medial plantar and posterior tibial arteries were confirmed and mapped using handheld acoustic Doppler ultrasound. A V-shaped flap was designed within the non-weight-bearing medial plantar (instep) region. The base of the V-flap was positioned posteriorly, contiguous with the anterior margin of the heel defect. The medial and lateral borders were delineated by the transition zones between the plantar skin and the medial/lateral foot surfaces, respectively. The apex of the V-shaped paddle was centred over the vascular axis, terminating approximately 2 cm proximal to the metatarsal heads to preserve the forefoot weight-bearing surface.

Surgical procedure:

- Debridement: The necrotic tissue at the heel was debrided and cleaned thoroughly.

- Pedicle exposure: The first incision was made at the tarsal tunnel area to expose the neurovascular pedicle, then extended along the medial border of the pre-designed flap. The abductor hallucis muscle was exposed and divided.

- Flap elevation: The flap was elevated beneath the abductor hallucis and flexor digitorum brevis muscles. The perforating vessels were dissected more deeply, and the medial plantar neurovascular bundle was included with the flap by retracting the abductor hallucis medially to maintain both perfusion and sensation.

- Sliding advancement: The flap was advanced posteriorly by sliding to completely cover the heel pad defect. This allowed for tension-free coverage.

- Closure: The flap was secured to the heel margins. The V-shaped donor site was either closed in a Y-fashion or, as in this series, covered with a split-thickness skin graft (STSG) harvested from the thigh.

- Postoperative management: The leg was placed in an elevated position. The skin graft dressing was removed after 5 days. Skin sutures or staples were removed after 2 weeks. The patient was instructed to perform ankle mobilisation exercises and gradual weight-bearing.

- Postoperative outcomes were assessed based on the following criteria: Primary wound healing, flap viability, ankle joint function, and flap sensory recovery.

- Good: Primary wound healing, complete flap survival, normal ankle mobility, and sensory recovery at the S3-S4 level.

- Fair: Secondary wound healing, partial flap necrosis, preserved ankle function, and sensory recovery at the S2 level.

- Poor: Secondary wound healing, partial flap necrosis, limited ankle function, and sensory recovery at the S0-S1 level.

Table 1. Patient characteristics.

Parameter	Case series data
Sample size	n=4 (2 male, 2 female)
Age range	3 to 52 years
Defect size	4x6 cm to 10x12 cm

3. Results

From October 2020 to February 2024, four patients with total heel pad defects were reconstructed with medial plantar artery flaps. The group included two males and two females, aged between 3 to 52 years (Table 1).

The size of the defects ranged from 4×6 cm to 10×12 cm. All injuries were caused by trauma. Two cases involved isolated heel wounds, while the other two had associated calcaneal fractures that were treated with internal fixation. In all cases, the heel wounds were initially closed primary, but later developed extensive soft-tissue necrosis over the entire heel pad.

Table 2. List of patients.

Case	Age/Sex	Defect size (cm)	Flap size (cm)	Associated injury	AOFAS score	BMRC score	Result
1	52/Female	7x9	8x9	None	100	S3	Good
2	3/Male	4x6	5x6	Calcaneal fracture	100	S4	Good
3	30/Male	8x9	9x10	None	100	S4	Good
4	19/Female	10x12	8x9	Calcaneal fracture	100	S3	Good

The smallest flap size was 5×6 cm, and the largest was 9×10 cm (Table 2). In one case with a large ankle and heel soft-tissue defect, we used a combination of a medial plantar

flap and a reverse-flow peroneal artery perforator flap with a V-Y advancement style, along with a split-thickness skin graft to achieve full coverage.

The follow-up time ranged from 12 months to 4 years. All four cases had good outcomes: the flaps survived completely and fully covered the total heel pad defects. Ankle and foot function after surgery scored 100 points according to the AOFAS (American Orthopaedic Foot and Ankle Society) scale. Sensory recovery reached S4 in two cases and S3 in two cases, based on the BMRC grading. There were no cases of heel ulceration during follow-up. Donor sites and skin grafts healed well, and no donor-site complications were observed. All patients were satisfied with both the functional and aesthetic outcomes after reconstruction.



Fig. 1. Preoperative (left) and postoperative (right) photos (A, B) Patient 1, female, 52 years old, (C, D) Patient 2, male, 3 years old, (E, F) Patient 3, male, 30 years old.

4. Discussion

Soft-tissue defects of the heel pad are relatively common and may result from trauma, burns, tumour resection, malignancy, or chronic ulcers associated with systemic conditions such as diabetes mellitus. However, total heel pad defects are relatively uncommon. The

heel possesses a specialised anatomical structure designed for weight-bearing, supporting approximately 80% of the body's weight during standing and ambulation. This structure is characterised by limited skin laxity compared with other regions, which makes primary closure of large defects in this area nearly impossible [3]. Moreover, the plantar surface of the foot has dense sensory innervation, which plays an essential role in weight distribution, proprioception, and protection from external trauma. Therefore, reconstruction of heel defects presents several challenges, including restoration of function, preservation of sensation, maintenance of contour, and an acceptable aesthetic outcome [7]. In our series, all patients presented with total heel pad defects due to trauma. Initial management included debridement and primary closure; however, all cases subsequently developed extensive skin necrosis in the heel region.

According to the literature review, heel soft-tissue defects are commonly small to moderate in size, typically resulting from trauma, pressure ulcers, or diabetic complications. For such defects, many authors have reported favourable outcomes using medial plantar artery island flaps. In cases involving extensive or total loss of the heel pad, reverse sural flaps or free flaps are more commonly used due to their larger size, good flap viability, and ability to provide adequate coverage. However, these flaps present several disadvantages, including pedicle torsion leading to venous congestion, the requirement for microsurgical techniques and equipment, and sometimes the need for secondary procedures such as flap thinning or pedicle division. Importantly, the anatomical soft-tissue structure of these flaps is not similar to the heel pad. The absence of fibrous septa within the subcutaneous fat leads to reduced stability under weight-bearing conditions. As a result, shearing of the subcutaneous fat may occur during ambulation. Additionally, these flaps typically offer limited sensory recovery [8, 9]. In our series, all four patients presented with complete loss of the heel pad. Due to the unique functional and structural requirements of the heel region, we decided to use medial plantar artery flaps for reconstruction. The flap was designed in a reversed V shape, allowing sufficient coverage area while preserving anatomical and sensory characteristics similar to those of the native heel pad. Postoperative outcomes in all four cases were favourable, with preserved heel function, good sensory recovery, and no occurrences of pressure ulceration due to sensory loss or lack of protective feedback.

The medial plantar artery flap was first described by D.H. Harrison, et al. (1981) [6]. It is designed in the medial plantar region, based on the medial plantar neurovascular bundle. This is a sensate fasciocutaneous flap that shares unique anatomical properties with the heel pad. Due to these similarities, the medial plantar flap is often the preferred option for reconstruction of small- to medium-sized heel defects. However, in most reports, the flap is designed as an island flap, and the maximum flap size that can typically be harvested is around 6×10 cm (covering the complete medial plantar area), which is usually insufficient

for covering total heel pad defects [10]. The key difference in our flap design lies in not restricting dissection to the medial plantar region or using the island flap design as traditionally described. Based on vascular supply principles, we extended the flap design laterally toward the border between the plantar and lateral aspects of the foot and posteriorly to the anterior edge of the heel defect. After flap elevation, it was rotated and advanced posteriorly to fully cover the defect. With this modified design, we were able to harvest a larger flap, up to 9×10 cm in size, providing adequate coverage for both the heel pad and part of the lateral plantar weight-bearing area.

Preoperative vascular assessment is an important step, particularly in patients with extensive ankle-foot trauma or in elderly patients with underlying vascular disease. According to N.T. Ly (1996) [11], angiography may not always be necessary, especially in patients with small, non-traumatic defects. In such cases, handheld Doppler ultrasound is often sufficient for vascular evaluation. In our study, all four cases involved large soft-tissue defects caused by traumatic mechanisms, which increased the risk of vascular injury in the ankle region. In one case involving complete loss of the heel pad and posterior heel, preoperative angiography revealed occlusion of the dorsalis pedis artery. We initially considered the risk of toe ischaemia due to potential sacrifice of the medial plantar artery during flap harvest. However, the flap transfer was performed six weeks post-injury, allowing collateral circulation to develop in the traumatic region. Intraoperatively, we temporarily clamped the medial plantar artery and confirmed adequate perfusion to the toes before ligating the artery and elevating the flap. A noteworthy feature of this case was the use of two flaps: the medial plantar flap for heel pad reconstruction and a reverse-flow peroneal artery perforator flap with a V-Y advancement pattern to cover the posterior heel defect, along with a split-thickness skin graft for the ankle region (Fig. 2). This case illustrates that, in complex, multi-regional soft-tissue defects of the hindfoot, the use of multiple local or regional flaps can provide adequate coverage without the need for free flaps.



Fig. 2. Patient 4, female, 19 years old, with a large ankle and heel soft-tissue defect. (A, B) Preoperative defect, **(C, D)** Intraoperative period, **(E, F)** 3 months postoperatively.

Based on our experience with four cases of total heel pad defects reconstructed using the medial plantar artery flap, several significant advantages were observed. These include the ability to debride and reconstruct the defect in a single-stage procedure, a reliable and consistent vascular pedicle, excellent flap viability, sensory innervation, and a similar anatomical structure to the heel pad. Importantly, our modified flap design allowed for harvesting a flap large enough to cover the entire weight-bearing area of the heel and lateral plantar region. The postoperative outcomes were excellent: All four flaps survived completely, ankle and foot function scored 100 points according to the AOFAS scale, and sensory recovery reached S3-S4 levels according to the BMRC scale (Table 2). These results strongly support the clinical utility of the medial plantar artery flap in heel reconstruction. Another notable advantage is that all postoperative scars were located on the ankle and plantar regions and did not interfere with movement or daily activities. All four patients reported satisfaction with both the functional and aesthetic outcomes at long-term follow-up.

The main limitation of this study is the very small sample size (n=4), which markedly limits the statistical power and generalisability of our findings. Therefore, the results should be interpreted with caution and considered preliminary and descriptive rather than definitive.

5. Conclusions

Heel soft-tissue defects require coverage with flaps that provide both sensation and a similar anatomical structure to ensure function and reduce the risk of ulceration after reconstruction. The medial plantar artery flap offers several advantages for heel reconstruction: A reliable vascular pedicle, good viability, anatomical similarity to the heel pad, and retained protective sensation. In particular, with an extended advancement flap design, it can provide sufficient size to cover total heel pad defects. Our study showed that all four cases using the medial plantar artery flap with a modified sliding-advancement technique to reconstruct total heel pad defects achieved good functional and aesthetic outcomes.

CRediT author statement

Xuan Thach Tran: Conceptualisation, Study design, Writing - Original draft preparation, Follow-up; Mai Anh Bui: Data collection, Writing - Original draft preparation, Follow-up; Thi Thu Phan: Surgical assistance, Data collection, Formal analysis, Writing - Reviewing and Editing; Trung Truc Vu: Surgical procedure, Conceptualisation, Methodology, Supervision, Writing - Reviewing and Editing.

COMPETING INTERESTS

The authors declare that there is no conflict of interest regarding the publication of this article.

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