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ARTICLE

# Reconstruction of the distal lower leg and foot sole with medial plantar flap: a retrospective study in one center

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**ABSTRACT**

Soft tissue reconstruction of the distal lower leg and foot sole is a challenge for surgeons. In this article, we describe our experience and outcomes with distal lower leg and foot sole reconstruction using the medial plantar flap. From January 2007 to December 2017, 29 consecutive patients from our department underwent reconstruction of soft tissue defects over the distal lower leg, heel and plantar forefoot using medial plantar flaps. Of the 29 patients, the defects were located in the distal lower leg ($n = 8$ [27.6%]), heel ($n = 14$ [48.3%]) and plantar forefoot ($n = 7$ [24.1%]). The mean follow-up period was 18.6 months, 28 (96.6%) survived completely. Lateral partial necrosis occurred in one flap. No patient had recurrence of ulcer and two (6.9%) patients died within 1 year post-reconstruction owing to metastatic malignant melanoma. At last follow-up, all survived patients could walk for more than 1 h in normal shoes. All donor sites were covered with a split-thickness skin graft, no early nor late complications were encountered, and no patients complained about the donor site scar. The medial plantar flap may be considered as an effective method for the repair of small to medium soft tissue defects in the distal lower leg, heel and plantar forefoot.

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Defect; distal lower leg; heel; plantar forefoot; medial plantar flap

## Introduction

Soft tissue reconstruction of the distal lower leg and foot sole is a challenge for surgeons because of the lack of locally available tissues for transposition and the special structural characteristics of this area [1–3]. The reconstruction requires durable and reliable flap coverage to allow for weightbearing and walking. Several available methods have been described; these include local flaps, pedicled flaps and free flaps. Local perforator flap is often unavailable because of variability of perforating vessels [4]. In addition, local perforator flap is often unable to repair anterior tibial defects due to the limited length of vascular pedicle. Free flap is extremely challenging and requires good vascularity of the blood vessel at the recipient site. In addition, the skin texture and deep structure of free flap are different from those of the distal lower leg and foot sole [5,6]. The available pedicled flaps are the sural neurovascular flap and medial plantar flap. The sural neurovascular flap has been used to repair the distal lower leg and posterior heel defects [7–9]. However, it usually results in bloated appearance, and obvious contour deformities at the donor site, and the flap bulk [10]. In addition, venous congestion and superficial necrosis of the distal part are often observed in this flap [11].

In contrast, the medial plantar flap has been reported for plantar reconstruction, especially heel, because of the concealed donor site, similar skin texture and deep structure, reliable blood supply. They have showed better flap survival with fewer complications outcomes [12–18]. To the best of our knowledge, the aesthetic and functional outcomes of reconstruction have not yet been critically analyzed. Therefore, we describe our experience and outcomes with the distal lower leg and foot sole reconstruction using the medial plantar flap.

## Patients and methods

### General data

From January 2007 to December 2017, 29 consecutive patients from our department underwent reconstruction of soft tissue defects over the distal lower leg, heel and plantar forefoot using medial plantar flaps. Of the 29 patients, 18 (62%) were males and 11 (38%) were females, and the patient age ranged from 20 to 77 (average 54.4) years. All defects were combined with exposed bones, tendons and/or fixation devices. The causes of defects included cancer resection ($n = 15$ [51.7%]) (14 [48.3%] cases of melanoma and 1 [3.4%] case of squamous cell carcinoma), trauma ($n = 6$ [20.7%]), chronic ulcer ($n = 5$ [17.2%]), electrical injury ($n = 3$ [10.3%]). The defects were located in the distal lower leg ($n = 8$ [27.6%]), heel ($n = 14$ [48.3%]) and plantar forefoot ($n = 7$ [24.1%]). The size of defects varied from 4 cm × 4 cm to10 cm × 10 cm. All 29 patients provided written informed consent.

### Surgical technique

For defects of the distal lower leg and heel, an anterograde medial plantar flap was harvested. Sequential incisions were made on the surface of the tarsal tunnel and on the medial and distal aspects of the flap. The medial extent of the flap was incised to the surface of the abductor hallucis. Dissection of the flap was

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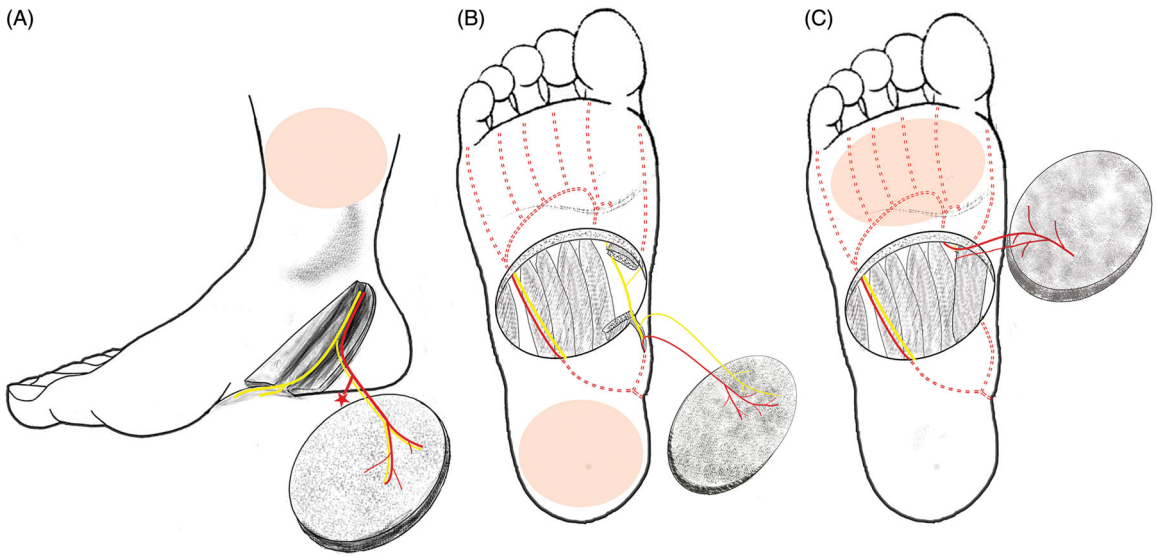


**Figure 1.** Range of applications of the medial plantar flap. (A) Defect in the distal lower leg. To cover the defect, the medial plantar artery is tracked proximally until a sufficient length is obtained. The lateral plantar artery is ligated when necessary. Star, the broken end of the lateral plantar artery. (B) Defect in the heel. (C) Defect in the forefoot area. The blood supply comes reverse from the deep plantar arch.

**Table 1.** Summary of flaps ($N = 29$ in 29 patients).

| Case | Age/sex | Recipient site | Flap size (cm × cm) | Flap types | Flap survival | Follow up (months) | Complications | VAS score | Functional recovery time |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 30/M | PF | 6 × 5 | RMPF | Yes | 6 | Pain | 9.5 | 6 |
| 2 | 40/M | PF | 5 × 4.5 | RMPF | Yes | 12 | Pain | 9.5 | 5 |
| 3 | 45/M | PF | 4.5 × 4.5 | RMPF | Yes | 12 | Pain | 10 | 6 |
| 4 | 60/M | PF | 5 × 5 | RMPF | Yes | 18 | Pain | 9 | 7 |
| 5 | 62/M | PF | 5.5 × 5 | RMPF | Yes | 18 | Pain | 9.5 | 7.5 |
| 6 | 60/F | PF | 6 × 5 | RMPF | Yes | 12 | Pain | 9 | 6.5 |
| 7 | 65/F | PF | 5.5 × 5.5 | RMPF | Yes | 6 | Pain | 10 | 6 |
| 8 | 58/M | Heel | 8 × 7.5 | AMPF | Yes | 24 | Pain | 9 | 7 |
| 9 | 60/M | Heel | 7.5 × 5.5 | AMPF | Yes | 12 | Pain | 9.5 | 7.5 |
| 10 | 62/M | Heel | 7 × 5 | AMPF | Yes | 12 | Pain | 9.5 | 9 |
| 11 | 62/F | Heel | 8 × 8 | AMPF | Yes | 12 | Pain | 9 | 10 |
| 12 | 65/F | Heel | 10 × 10 | AMPF | Yes | 20 | Pain, numbness | 8 | 18 |
| 13 | 68/M | Heel | 8 × 8 | AMPF | Yes | 6 | Pain | 9 | None |
| 14 | 77/F | Heel | 6 × 5 | AMPF | Yes | 12 | Pain | 10 | 9.5 |
| 15 | 20/F | Heel | 10 × 6.5 | AMPF | Yes | 60 | Pain | 8 | 7 |
| 16 | 58/M | Heel | 7 × 7 | AMPF | Yes | 12 | Pain | 8.5 | 8.5 |
| 17 | 65/M | Heel | 9 × 8 | AMPF | Yes | 18 | Pain | 8.5 | 11 |
| 18 | 65/F | Heel | 7 × 6 | AMPF | Yes | 18 | Pain | 9 | 10.5 |
| 19 | 67/F | Heel | 9 × 7 | AMPF | Yes | 12 | Pain | 8 | 11 |
| 20 | 52/M | Heel | 6.5 × 6.5 | AMPF | Yes | 24 | Pain | 10 | 9.5 |
| 21 | 59/M | Heel | 10 × 6 | AMPF | Yes | 12 | Pain | 8 | None |
| 22 | 22/M | DLL | 8 × 8 | AMPF | Yes | 48 | Pain, numbness | 7 | 7 |
| 23 | 42/F | DLL | 5 × 4.5 | AMPF | Yes | 24 | Pain | 7.5 | 18 |
| 24 | 44/F | DLL | 8 × 8 | AMPF | Yes | 24 | Pain | 7 | 9 |
| 25 | 47/M | DLL | 8 × 7 | AMPF | Yes | 30 | Pain | 8 | 7.5 |
| 26 | 60/M | DLL | 7 × 4.5 | AMPF | partial necrosis | 12 | Pain | 8 | 8 |
| 27 | 62/F | DLL | 9 × 8 | AMPF | Yes | 12 | Pain | 7 | 11.5 |
| 28 | 49/M | DLL | 5 × 4 | AMPF | Yes | 23 | Pain | 9 | 8 |
| 29 | 51/M | DLL | 6 × 5.5 | AMPF | Yes | 24 | Pain | 8.5 | 9 |

Abbreviations: AMPF: anterograde medial plantar flap; DLL: distal lower leg; F: female; M: male; PF: plantar forefoot; RMPF: reverse medial plantar flap; VAS: visual analog scale.

continued to the lateral margin of the abductor hallucis, and the abductor hallucis was cut off. It is worth noting that if a long vascular pedicle was not required, the abductor hallucis was not cut off. Then, the proximal stump of the muscle was elevated, and the ankle tunnel was opened continuously in a proximal direction until the posterior tibial artery and its branches (medial plantar and lateral arteries) was exposed. The distal extent of the flap was incised to locate the medial plantar neurovascular bundle. After the bundle was divided and ligated, the designed flap was elevated proximally below the level of the plantar aponeurosis. For distal lower leg defect, if necessary, the lateral plantar artery could be ligated to extend the length of the vascular pedicle. The pedicle was prevented from compressing and distorting when the flap was transferred to the recipient site through the tunnel (Figure 1(A,B)).

For plantar forefoot defects, a reverse medial plantar flap was harvested. Sequential incisions were made to form the medial, proximal and lateral extents of the flap. The medial extent of the flap was incised to the surface of the abductor hallucis. The proximal and lateral extents of the flap were incised to the deep layer of the plantar aponeurosis. Then, the proximal neurovascular bundle was exposed and ligated as described above and then sutured

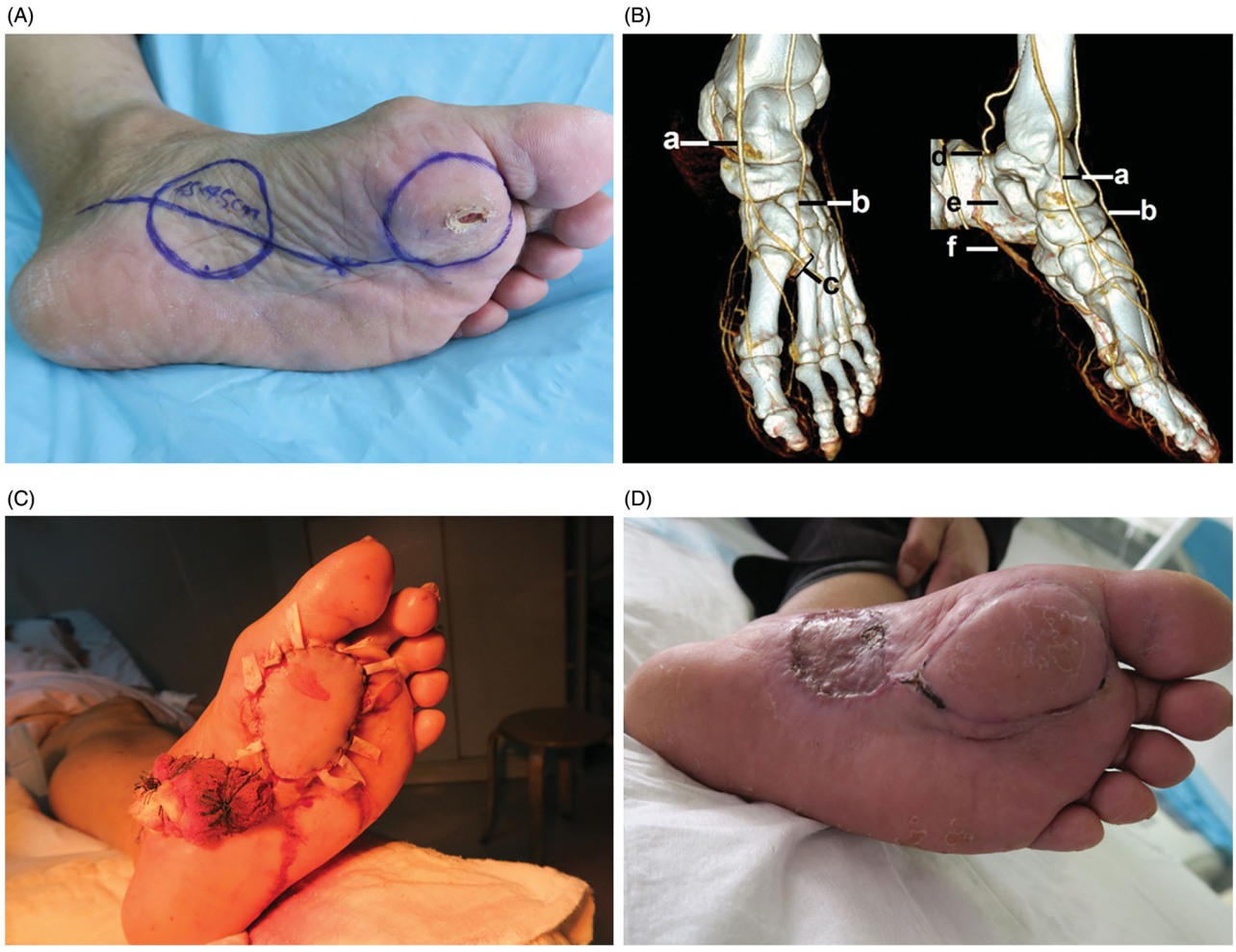


Figure 2. Typical case 1. (A) A 65-year-old man had a melanoma in the left forefoot sole. The design of reverse medial plantar flap was showed. (B) Computed tomography angiography scan showed the dorsalis pedis artery to the deep plantar arch, posterior tibial artery, and medial and lateral plantar arteries: (a) great saphenous vein; (b) dorsalis pedis artery; (c) deep branch of dorsal pedis artery to plantar; (d) posterior tibial artery; (e) medial plantar artery; (f) lateral plantar artery. (C) A 4.5 × 4.5 cm medial plantar flap was raised and transferred to repair the defect. (D) The flap had an excellent aesthetic appearance and functional recovery without any donor site deformity.

to the plantar fascia to prevent avulsion. The flap was elevated from the proximal to the distal end. The skin and soft tissue between the flap and the defect were cut off. Then, the flap was transferred to the forefoot defect (Figure 1(C)).

All donor sites were covered with split-thickness skin grafts.

### *Postoperative management and follow-up outcome evaluation*

Postoperatively, the patients were maintained on strict bed rest with the foot elevated. Blood circulation to the flaps was monitored by observing color, temperature and the capillary filling sign. The skin graft was fixed with appropriate pressure. Nine days after surgery, the dressings were removed to determine whether the skin grafts survived. The patients were asked to avoid weightbearing and walking for about 3–4 weeks.

At the final follow-up, patient satisfaction with the aesthetic recovery of the reconstructed area was evaluated using a visual analog scale (VAS). The score ranged from 0 (complete dissatisfaction) to 10 (complete satisfaction). Patients recording a score of $\geq$8 were considered satisfied with the aesthetic result and those recording a score $<$8 were considered less satisfied [19]. The functional recovery was evaluated using the time from operation to walking for more than 1 h in normal shoes.

### *Statistical analysis*

Patients were divided into three groups based on the location of the defect: plantar forefoot group, heel group and distal lower leg group. The VAS score and the functional recovery time of each group were presented as Mean ± SD (standard deviation). Unpaired student's *t* test was conducted between any two groups. All the clinical data were analyzed by using SPSS 19.0 software package (SPSS Inc, Chicago, IL). The level of significance was set at $p < .05$.

## Results

We reviewed a total of 29 medial plantar flaps, including 22 (75.9%) anterograde medial plantar flaps, and 7(24.1%) reverse medial plantar flaps. The flap sizes ranged from 4.5 × 4.5 cm to 10 × 10 cm. The reconstituted area included the distal lower leg ($n = 8$ [27.6%]), the heel ($n = 14$ [48.3%]) and the plantar forefoot ($n = 7$ [24.1%]). The mean follow-up period was 18.6 (range 6–60) months. Of the 29 flaps, 28 (96.6%) survived completely. Lateral partial necrosis occurred in one anterograde flap. This might have been related to vascular sclerosis caused by diabetes mellitus, and the remaining defect was successfully covered using skin graft.

No arterial crisis or venous congestion occurred in reverse flaps. No patient had recurrence of ulcer and two (6.9%) patients died within 1 year post-reconstruction owing to metastatic malignant melanoma. Of the 27 survived patients, two (7.4%) patients had a transient feeling of numbness on the big toe, which had disappeared within eight postoperative months, and all patients had a difference level pain which had gradually disappeared within six postoperative months (Table 1).

At last follow-up, all survived patients could walk for more than 1 h in normal shoes. In the plantar forefoot group and heel group, 21 (100%) patients were satisfied with the cosmetic appearance of the flap (VAS score $\geq$8). In the distal lower leg group, four (50%) patients complained about the flap appearance (VAS score $<$ 8). All donor sites were covered with a split-thickness skin graft, no early nor late complications were encountered, and none of patients complained about the donor site scar.

### Case presentations

#### Case 1: Reconstruction of plantar forefoot with reverse medial plantar flap

A 65-year-old man was diagnosed with malignant melanoma on his left forefoot sole (Figure 2(A)). The deep plantar arch was proven to exist by preoperative CTA examination (Figure 2(B)). After a wide excision, a tumor-free defect measured 4.5 × 4.5 cm was noted. A 4.5 × 4.5 cm medial plantar flap was raised and transferred to repair the defect (Figure 2(C)). The donor site was covered with a split-thickness skin graft. The follow-up time was 6 months. Flaps survived without complication and the aesthetic result was excellent (Figure 2(D)).

#### Case 2: Reconstruction of heel with medial plantar flap

A 52-year-old man was diagnosed with malignant melanoma on his left heel (Figure 3(A)). After a wide excision, a tumor-free defect measured 6 × 6 cm was noted. A 6.5 × 6.5 cm medial plantar flap was raised and transferred to repair the defect (Figure 3(B)). The donor site was covered with a split-thickness skin graft. The follow-up time was 24 months. The flap had an excellent aesthetic appearance and functional recovery with a concealed donor site (Figure 3(C)).

#### Case 3: Reconstruction of distal lower leg with medial plantar flap

A 42-year-old woman was involved in a motor vehicle accident and suffered open distal tibia and fibula fractures and defect of large area skin and soft tissue. After most of the wounds to her right leg were repaired with skin grafts, there was still a defect with tibial exposure, which was measured 4.5 × 4 cm (Figure 4(A)). DSA examination revealed that the peroneal artery was disrupted above ankle joint (Figure 4(B)). A 5 × 4.5 cm medial plantar flap was raised and transferred to reconstruct the defect (Figure 4(C)). The donor site was covered with a split-thickness skin graft. The follow-up time was 24 months. The patient had full functional recovery with acceptable cosmetic result with a concealed donor site (Figure 4(D)).

## Discussion

The distal lower leg and foot sole have inherent characteristics that can make even a small defect a challenge, and the soft tissue defect of this region requires durable and reliable flap coverage. The most widely accepted flap that has similar characteristics to this region is a medial plantar flap, which several authors have reported as yielding satisfactory results [12–18].

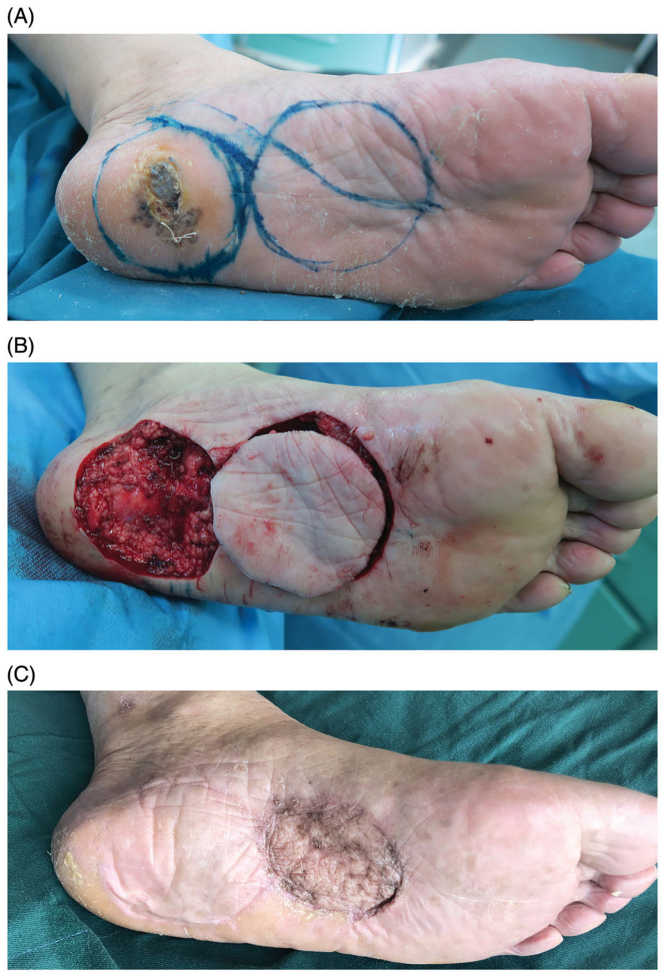


Figure 3. Typical case 2. (A) A 52-year-old man was diagnosed with malignant melanoma on his left heel. (B) Extended resection and flap harvest were performed. (C) At the 24-month follow-up, the flap had an excellent aesthetic appearance and functional recovery with a concealed donor site.

The medial plantar flap is a fasciocutaneous island flap raised from the non-weight-bearing instep of the plantar foot. It has remarkably little impact on the appearance of the foot because of its concealed position, and does not affect the walking function of the foot because of its non-weight-bearing characteristic [20,21]. In this study, all donor sites were covered with a split-thickness skin graft, and all patients were very satisfied with the appearance of donor site. No patient complained about walking disorders caused by pain, ulceration, deformity of donor site.

The flap offers similar skin texture to the foot sole, many reports have shown that the flap had excellent skin color matching in foot reconstruction [12]. However, few reports describe the outcomes of the reconstruction of the distal lower leg with this flap. In our study, all patients in the plantar forefoot group and heel group were very satisfied with the aesthetic appearance of flaps (VAS score $\geq$8) (Table 2). While, four (50%) patients in the distal lower leg group complained that there were obvious incision marks and skin color difference. There was a statistically significant difference between the distal lower leg group and the plantar forefoot group, between the distal lower leg group and the heel group (7.8 ± 0.8 vs 9.5 ± 0.4, $p = .000$, 7.8 ± 0.8 vs 8.8 ± 0.6, $p = .003$) (Table 2). There are three reasons for this result. First, the flap was closer to the heel and planta forefoot than the distal

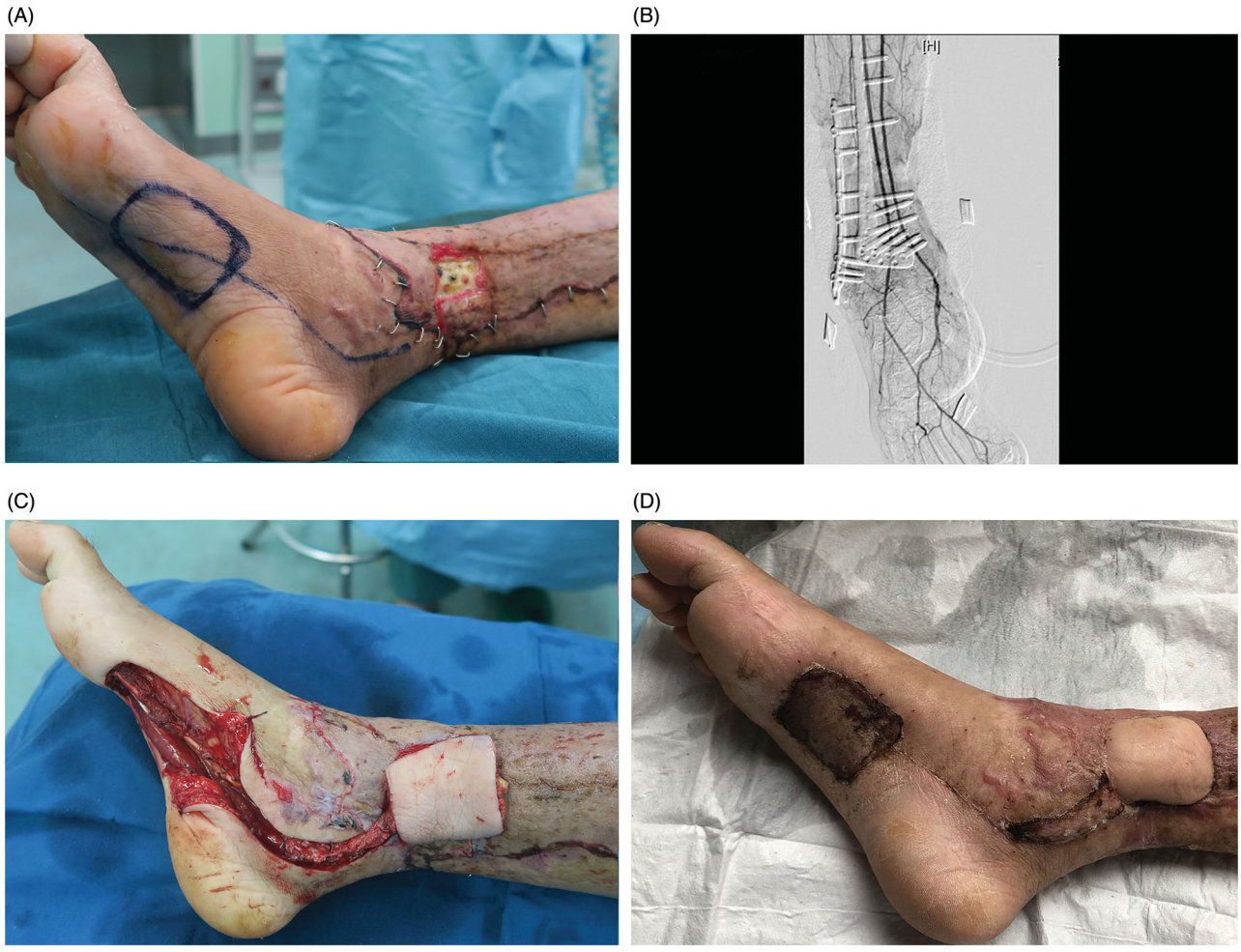


**Figure 4.** Typical case 3. (A) The design of medial plantar flap was showed. (B) DSA examination revealed that the peroneal artery was disrupted above ankle joint. (C) A 5 × 4.5 cm medial plantar flap was raised and transferred to reconstruct the defect. (D) At the 24-month follow-up, the patient had full functional recovery with acceptable cosmetic result.

**Table 2.** Appearance and functional recovery results.

| | Plantar forefoot | Heel | Distal lower leg | *p* Value | Total result |
|---|---|---|---|---|---|
| VAS score ($n = 29$) | 9.5 ± 0.4 | 8.8 ± 0.6 | – | 0.015 | 8.7 ± 0.9 |
| | 9.5 ± 0.4 | – | 7.8 ± 0.8 | 0.000 | |
| | – | 8.8 ± 0.6 | 7.8 ± 0.8 | 0.003 | |
| Functional recovery time(months) ($n = 27$) | 6.3 ± 0.8 | 9.9 ± 2.9 | – | 0.006 | 8.9 ± 3.1 |
| | 6.3 ± 0.8 | – | 9.8 ± 3.6 | 0.028 | |
| | – | 9.9 ± 2.9 | 9.8 ± 3.6 | 0.933 | |

Abbreviations: VAS: visual analog scale.

lower leg that explained why the color and texture of the flap matched better with the heel and plantar forefoot. Second, patients of the plantar forefoot group and the heel group had a higher appearance satisfaction because the reconstructed area was completely concealed when standing or walking. Third, flaps for plantar forefoot and heel reconstruction bore the burden, and the gravity compression inhibits scar proliferation [22]. Despite incision marks and skin color difference, no one complained of bulky flaps. This flap can still achieve acceptable appearance reconstruction results for patients with distal lower leg defects.

The flap offers durable fasciocutaneous tissue with histologic similarities to the distal lower leg and foot sole. The vertical fiber structure between the skin and the deep structures enhances the stability of the skin to adapt to weight bearing and to resist shearing forces. At last follow-up, all survived patient had full functional recovery and the mean time from operation to walking for more than 1 h in normal shoes was 8.9 ± 3.1 months (Table 2). This flap is reliable enough to reconstruct the walking function of the distal lower leg and foot sole. Patients with heel defects had more functional recovery time than those with plantar forefoot defects (9.9 ± 2.9 months vs 6.3 ± 0.8 months; $p = .006$) (Table 2). This was because the heel bore more pressure than the plantar forefoot, causing more severe pain when patients began walking training. According to feedback of patients, pain is the main obstacle of walking. Patients with distal lower leg defects whose flaps did not bore vertical pressure, like those with heel defects, needed a longer time to recover walking function than those with plantar forefoot defects (9.8 ± 3.6 months vs 6.3 ± 0.8 months; $p = .028$) (Table 2). This result was in large part because most distal lower leg defects were caused by trauma associated with fractures, not only related to the pain caused by flap transplantation.

Therefore, the pain and fracture might be the main reason for the difference in functional recovery.

The pedicle is constituted by the medial plantar artery and its venae comitantes and the cutaneous branch of the medial plantar nerve [23–25]. The medial plantar artery is not the dominant blood supply source of the plantar, and it plays a relatively minor role in the blood flow of the foot because the blood flow of the deep plantar arch mainly comes from the lateral plantar artery and branches of the dorsalis pedis artery [20]. This artery's sacrifice will not affect the prognosis of the plantar. On the other hand, the medial plantar artery has sufficient diameter to ensure good blood supply of the flap [23]. Thus, we removed the superfluous soft tissue and got a slender vascular pedicle that had a high flexibility to rotate the flap. No flap had difficulty in rotation during the operation, even though some of the patients had the distal lower leg defect. No patient complained of bloated pedicle after operation. This advantage is particularly evident in the repair of distal lower leg defect when compared with sural flaps. Herlin, in his study of patients who underwent ankle defect reconstruction using the sural flap, reported a major ankle bulking [11].

In fact, the repair range of medial plantar flap depends on the length of the vascular pedicle. When the medial plantar flap is used to repair heel defect, the medial plantar artery is long enough to cover heel defect without ligating the lateral plantar artery (Figure 1(B)). When the defect is located in the distal lower leg, the length of the pedicle is sometimes too short to reach the defect, and the branch of the lateral plantar artery of the posterior tibial artery is usually ligated to extend the length of the vascular pedicle (Figure 1(A)). Ligation of the medial and lateral plantar arteries sacrifices the main blood supply of the foot sole [26]. Vascularization of the foot sole is supported only by communications from the dorsalis pedis and peroneal arteries, which can be inadvisable in patients with the dorsalis pedis and peroneal arteries injured or vascular disease. Therefore, preoperative Doppler ultrasonography or CTA exploration is mandatory to confirm that communications are present and that the plantar arch is supplying blood. In eight cases of medial plantar flap for distal lower leg defect, three cases underwent ligation of the lateral plantar artery to lengthen the pedicle during operation. During the observation and long-term follow-up after operation, no ischemia was found in the foot and no complications were complained about the foot. For plantar forefoot defects, we choose the reverse medial plantar flap (Figure 1(C)). The blood flow of flap mainly comes from the deep plantar arch anastomosed with the lateral plantar artery and the deep plantar branch of the dorsalis pedis artery [27,28]. Vascular exploration is mandatory to confirm the presence of the plantar artery arch preoperatively. Before the proximal trunk of the medial plantar artery is cut, it is necessary that the proximal blood flow of flap is blocked for 5 min to observe the flap nutrition.

The medial plantar flap has some limitations. The flap is only suitable for small to medium-sized defects because the maximum size of the flap is $10 \times 8$ cm according to the previous reports [12,17,29]. In this study, the maximum size of the flap was $10 \times 10$ cm, which is consistent with previous reports.

In conclusion, the medial plantar flap may be considered as an effective method for the repair of small to medium soft tissue defects in the distal lower leg, heel and plantar forefoot. It provides the concealed donor site, excellent aesthetic appearance and full functional recovery with few complications. In addition, the medial plantar flap has the best aesthetic appearance for heel and plantar forefoot reconstruction and the fastest functional recovery for plantar forefoot reconstruction.

## Disclosure statement

No potential conflict of interest was reported by the authors.

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