

# Reconstruction of extensive plantar forefoot defects with free anterolateral thigh flap

Lei Chen, MD, PhD, Zhixin Zhang, MD, PhD, Ruijun Li, MD, PhD, Zhigang Liu, MD, PhD, Yang Liu, MD, PhD\*

## Abstract

**Purpose:** The aim of the soft tissue reconstruction of plantar forefoot should yield weight-bearing function and aesthetic contour, which poses a significant challenge for reconstructive surgeons to provide an appropriate flap according to the “like for like” reconstructive principle. Local flaps and pedicled flaps have been described for the reconstruction of small- to medium-sized defects of plantar forefoot and achieved optimal results. However, reconstruction of extensive defects of plantar forefoot is rarely investigated. In this study, we present our experience using the free anterolateral thigh (ALT) flap in the reconstruction of extensive defects of plantar forefoot.

**Methods:** Between November 2011 and April 2017, 9 patients were treated for extensive soft tissue defects in the plantar forefoot areas with ALT flaps. The mean age at the time of surgery was 39.3 years (range, 25–64 years).

**Results:** The follow-up period ranged from 12 to 77 months, with a mean of 31 months. All flaps survived well, and the patients were satisfied with the aesthetic and functional results. The size of the flaps ranged from 63 to 455 cm<sup>2</sup>, with a mean of 197.7 cm<sup>2</sup>. Seven patients with no bony involvement began to gradually weight-bear at 3 weeks postoperatively. During the follow-up time, postoperative ulceration at the reconstructed weight-bearing areas was not encountered.

**Conclusion:** The ALT flap is a reliable option for treatment of extensive defects of plantar forefoot, resulting in an optimal functional and aesthetic outcome. Even when a total plantar loss exists, excellent results can be achieved.

**Abbreviations:** ALT = free anterolateral thigh, FTSG = full-thickness skin graft.

**Keywords:** anterolateral thigh flap, free flap, plantar defects, plantar reconstruction, weight-bearing sole reconstruction

## 1. Introduction

The plantar forefoot is a vital weight-bearing area that allows humans to stand up and walk.<sup>[1]</sup> The specialized histological features of plantar forefoot provide the non-shearing and padding properties, which make it quite resistant and strong.<sup>[2]</sup> These anatomic and functional characteristics are unique for the sole of forefoot and its amputation has a severely adverse effect on weight-bearing and normal gait.<sup>[3]</sup> Therefore, the reconstructive surgeons face great difficulties to repair the complex skin and

soft tissue defects of the plantar forefoot caused by various traumas, scar removal, or tumor resection. The ideal reconstruction of the plantar forefoot should restore weight-bearing function successfully in daily activities and appropriate contour to wear normal shoes.

Conventional local flaps or pedicled flaps from the non-weight-bearing area, such as instep flaps, can be used to achieve optimal reconstruction of the plantar forefoot, leading to excellent functional, and aesthetic results.<sup>[4–6]</sup> However, they are limited to small- to medium-sized defects. For larger and extensive soft tissue defects of plantar forefoot, microvascular flap reconstruction is required. In various microvascular flaps, skin-grafted muscle flaps, and fasciocutaneous flaps are the main reconstructive options for sole defects, but controversy remains.<sup>[7–12]</sup> These free flaps also have their limitations, such as high ulceration rates, significant donor site morbidity, and flap instability. Moreover, the studies involving the reconstruction of extensive defects of plantar forefoot are rare.

The free anterolateral thigh (ALT) flap, first introduced by Song et al,<sup>[13]</sup> is a reliable and versatile method for soft-tissue coverage of ankle and foot.<sup>[14,15]</sup> It has many attracting advantages for soft tissue reconstruction, including the long vascular pedicle, sufficient diameter for microanastomosis, large bulk for coverage, and minimal donor site morbidity. Therefore, this flap has great potential for the soft tissue reconstruction of massive defects of plantar forefoot with good characteristics different from those of skin-grafted muscle and fasciocutaneous flaps. So far, to our knowledge, the soft tissue reconstruction of plantar forefoot using an ALT flap has not been investigated in detail. The goal of this study is to evaluate the use of ALT flap for the reconstruction of extensive defects of the plantar forefoot with a long follow-up and present our clinical experience.

Editor: Jacopo Desiderio.

This work was supported by the National Natural Science Foundation of China (No. 81901245).

The authors have no conflicts of interest to disclose.

All data generated or analyzed during this study are included in this published article [and its supplementary information files].

Department of Hand and Foot Surgery, the First Hospital of Jilin University, Changchun, Jilin, China.

\* Correspondence: Yang Liu, Department of Hand and Foot Surgery, the First Hospital of Jilin University, Changchun 130021, Jilin, China (e-mail: yangliu86328@163.com).

Copyright © 2020 the Author(s). Published by Wolters Kluwer Health, Inc. This is an open access article distributed under the terms of the Creative Commons Attribution-Non Commercial License 4.0 (CCBY-NC), where it is permissible to download, share, remix, transform, and buildup the work provided it is properly cited. The work cannot be used commercially without permission from the journal.

How to cite this article: Chen L, Zhang Z, Li R, Liu Z, Liu Y. Reconstruction of extensive plantar forefoot defects with free anterolateral thigh flap. *Medicine* 2020;99:50(e20819).

Received: 11 January 2019 / Received in final form: 14 February 2020 / Accepted: 18 May 2020

<http://dx.doi.org/10.1097/MD.00000000000020819>

## 2. Patients and methods

Our study was approved by the Ethics Committee of the First Hospital of Jilin University and all patients involved in this work provided written informed consent. From November 2011 to April 2017, 9 patients with extensive plantar forefoot defects were treated with ALT flaps. Seven of all patients were male, and the other 2 patients were female. The mean age at the time of surgery was 39.3 years (range, 25–64 years). The massive defects were secondary to trauma in eight cases involving weight-bearing area defects, and unstable scar in 1 case. Eight of the cases were plantar forefoot defects and the remaining one was the total defect of plantar foot. Patient characteristics are presented in Table 1.

Preoperative evaluations were performed for every patient, including the size and location of defects, simple radiographs of the injured foot, and Doppler mapping. Thorough debridement was carried out for all wounds. To avoid secondary infection, we used vacuum-assisted closure for the acute trauma, and subsequent reconstruction of soft tissue defects was performed using an ALT flap. The flap was raised in the manner described in previous studies.<sup>[15,16]</sup> The exploration and dissection of the recipient vessels were completed before the elevation of flaps intraoperatively. Bone fixation was done using *k*-wires at the time of initial debridement. After transfer, the donor sites were closed through primary closure or full-thickness skin graft (FTSG).

Low-molecular-weight heparin calcium was administered subcutaneously for anticoagulation for 3 days postoperatively. The flaps were monitored subjectively, and the flap color, capillary refill, and temperature were observed closely in order to predict any changes in flap condition. Patients with no associated fracture were permitted to gradually weight-bear on the flap with crutches at 3 weeks postoperatively. When required, the flap debulking was carried out 4 months after the initial surgery.

During the follow-up period, functional and aesthetic outcomes were evaluated by way of donor-site complications, flap contour, ulcer formation, sensory recovery, flap stability, and the possibility of return to normal footwear. Light touch, pinprick, and deep pressure were examined to evaluate the sensibility of the flap. In our scoring system of sensibility, 1 point was awarded for every positive result in each test. Therefore, sensibility in a flap was regarded as good with a score of 3 points, fair with 2 points, and poor with 1 point. Sensory recovery was also assessed by 2-point discrimination. The soft-tissue stability of the flap was classified into 4 types: no soft-tissue breakdown was regarded as excellent; only occasional, rapidly healing breakdown as good; more frequent or slower healing but superficial breakdown as fair; constant deep ulceration as poor.

## 3. Results

Follow-up period of the 9 patients ranged from 12 to 77 months, with a mean of 31 months; all flaps survived well. The size of the flaps ranged from 63 to 455 cm<sup>2</sup>, with a mean of 197.7 cm<sup>2</sup>. In artery anastomosis, “end-to-end” fashion was used in 4 patients. The “end-to-side” technique was applied in the other 5 patients. The recipient artery used was either dorsalis pedis artery (4 cases) or posterior tibial artery (5 cases). The recipient veins of 5 patients were posterior tibial vein and great saphenous vein, and those of the other 4 cases were great saphenous vein and an accompanying vein of the artery.

Closure of the donor site depended on skin laxity, and primary closure was achieved in 2 cases (Table 2). However, donor sites were covered with FTSG in 7 cases. Patients did not have significant problems with the donor sites, such as dehiscence and partial skin grafting necrosis. However, the donor site of 1 patient produced hypertrophic scar. During the follow-up, 5 patients received debulking operation so that they were able to wear normal shoes. Intraoperative and postoperative characteristics are presented in Table 3.

Seven patients with no bony involvement began to gradually weight-bear at 3 weeks postoperatively. However, 2 patients were permitted to partially weight-bear at the sixth week after soft tissue reconstruction due to the fractures of the metatarsal bones. During the entire follow-up period, postoperative ulceration at the reconstructed weight-bearing areas was not encountered. Sensory recovery was evaluated for the flaps without debulking procedure at 12 months after reconstruction, and those with debulking procedure at 12 months after debulking surgery. According to our scoring classification, the sensibility of 4 flaps was graded as good, 5 flaps as fair. The stability of 3 flaps was graded as excellent, 4 as good, and the remaining 2 as fair. Two-point discrimination of these flaps was not detected obviously. As shown in Table 4, the satisfying sensory recovery might contribute to the good soft-tissue stability of the flap. All the patients were satisfied with the functional and aesthetic results.

## 4. Case reports

### 4.1. Case 1

A 26-year-old male patient (case number 2 in Table 1) presented with a necrotic wound on the right forefoot, which had developed as a result of crushing injury of his right foot. After soft tissue debridement, *k*-wires were used to fix the fractures of the first and second metatarsal bones. The size of defect was 18 × 10 cm<sup>2</sup>, and an ALT flap measuring 22 × 12 cm<sup>2</sup> was applied to repair the

**Table 1**

**Patient characteristics.**

Case	Age (yr)	Sex	Etiology	Defect Location	Defect Size (cm <sup>2</sup> )	Follow-up Time (mo)
1	25	Male	Trauma	Right plantar forefoot	10 × 8	32
2	26	Male	Trauma	Right plantar forefoot	18 × 10	18
3	41	Male	Trauma	The total right plantar foot	30 × 11	25
4	31	Male	Trauma	Left plantar forefoot	20 × 9	77
5	64	Male	Trauma	Right plantar forefoot	13 × 7	12
6	48	Male	Unstable scar, previous trauma	Right plantar forefoot	8 × 6	36
7	35	Female	Trauma	Left plantar forefoot	19 × 8	40
8	32	Female	Trauma	Right plantar forefoot	10 × 7	25
9	52	Male	Trauma	Left plantar forefoot	17 × 8	21

The total right plantar foot means the plantar forefoot, midfoot, and hindfoot of the right foot.

**Table 2**  
**Aesthetic outcome.**

Aesthetic Outcome	Percentages	
	Donor Site	
Primary Closure		22%
Skin Graft		78%
Hypertrophic Scar		11%
	Recipient Site	
Flap Bulkiness		56%

area. FTSG was performed for the donor site. The arterial anastomosis was carried out through “end-to-side” fashion onto the posterior tibial artery, and the recipient veins included posterior tibial vein and great saphenous vein. The flap survived completely, and the outcomes were satisfactory (Fig. 1).

**4.2. Case 2**

A 41-year-old male patient (case number 3 in Table 1) sustained a degloving injury to his right foot with a massive defect of the dorsal and plantar foot after a vehicle accident. In the initial surgery, the degloved skin was thinned to full-thickness skin to graft in situ after thorough debridement. After another 2 debridement procedures, we observed that the skin grafting of

**Table 4**  
**Correspondence between sensation and stability of the flaps.**

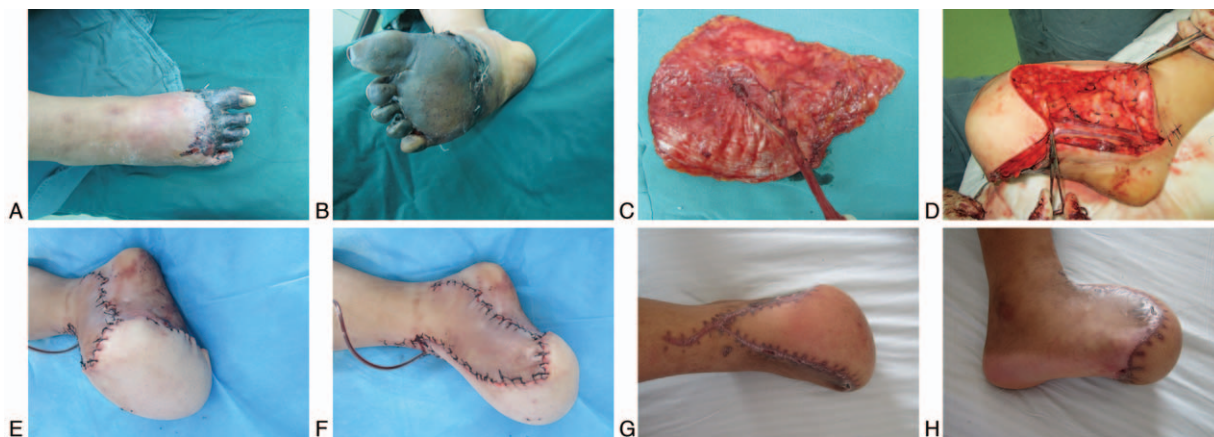
Stability	Sensory Recovery	
	Good	Fair
Excellent	3	
Good	1	3
Fair		2

the dorsal foot almost completely survived. However, the plantar skin grafting was entirely lost, which resulted in a 30 × 11 cm<sup>2</sup> size of plantar defect. To cover the total defect of plantar foot, an extended ALT flap measuring 35 × 13 cm<sup>2</sup> was chosen to reconstruct the total sole, including all weight-bearing zones. To the best of our knowledge, we firstly reported the soft tissue reconstruction of the total plantar foot with an ALT flap. FTSG was used to cover the donor site. The arterial anastomosis was completed through “end-to-side” fashion onto the posterior tibial artery, and the recipient veins consisted of posterior tibial vein and great saphenous vein. The donor site and the flap survived well. The patient was quite content with the contour and was able to ambulate in normal shoes after debulking procedures. Moreover, no ulceration occurred over the weight-bearing areas during a 25 month follow-up (Fig. 2).

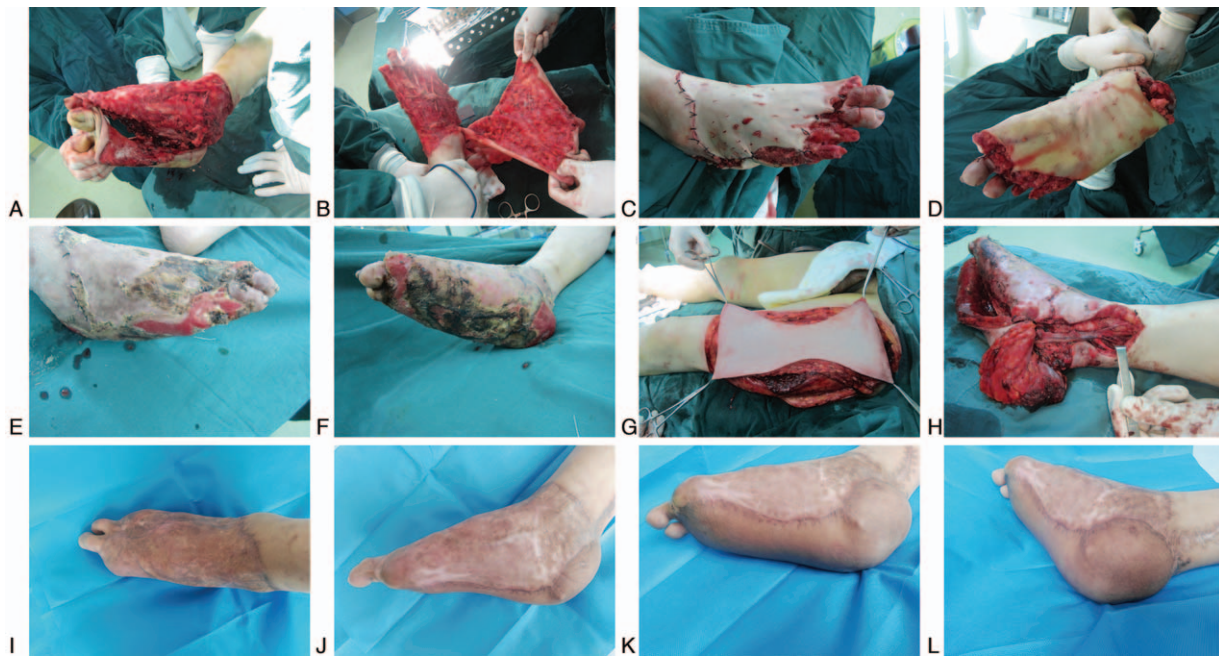
**Table 3**  
**Intraoperative and postoperative characteristics.**

Case	Flap size (cm <sup>2</sup> )	Flap from ipsilateral or contralateral foot	Recipient artery	Arterial anastomosis fashion	Recipient vein	Donor site closure	Debulking operation	Delayed ulceration	Normal shoes
1	12 × 10	Ipsilateral	DPA	End-to-end fashion	GSV and DPV	FTSG	Yes	None	Yes
2	22 × 12	Ipsilateral	PTA	End-to-side fashion	PTV and GSV	FTSG	Yes	None	Yes
3	35 × 13	Contralateral	PTA	End-to-side fashion	PTV and GSV	FTSG	Yes	None	Yes
4	23 × 11	Ipsilateral	PTA	End-to-side fashion	PTV and GSV	FTSG	Yes	None	Yes
5	15 × 8	Contralateral	DPA	End-to-end fashion	GSV and DPV	FTSG	No	None	Yes
6	9 × 7	Contralateral	DPA	End-to-end fashion	GSV and DPV	PC	No	None	Yes
7	21 × 10	Contralateral	PTA	End-to-side fashion	PTV and GSV	FTSG	Yes	None	Yes
8	13 × 8	Contralateral	DPA	End-to-end fashion	GSV and DPV	PC	No	None	Yes
9	19 × 10	Ipsilateral	PTA	End-to-side fashion	PTV and GSV	FTSG	No	None	Yes

DPA=dorsalis pedis artery, DPV=dorsalis pedis vein, FTSG=full-thickness skin graft, GSV=great saphenous vein, PC=primary closure, PTA=posterior tibial artery, PTV=posterior tibial vein.



**Figure 1.** The patient in case 1. Preoperative photographs of extensive soft tissue necrosis of forefoot (A and B); intraoperative photograph after elevation of the free anterolateral thigh flap (C); the elevated free anterolateral thigh flap was used to cover the defect (D); early postoperative photographs of the flap (E and F); 4 month follow-up with healed soft tissue envelope (G and H).



**Figure 2.** The patient in case 2. Preoperative photographs of the degloved foot (A and B); intraoperative photographs of skin grafting in situ (C and D); postoperative photographs of skin grafting (E and F); intraoperative photograph after elevation of the ALT flap (G); the elevated ALT flap was applied to cover the defect (H); 25 month follow-up with healed soft tissue envelope (I to L).

## 5. Discussion

Obviously, the optimal reconstruction of any defect should result in the best functional and morphological outcomes, with donor-zone morbidity kept to a minimum. In forefoot weight-bearing areas, including the first and fifth metatarsal heads, extraordinary stability, and mechanical resistance are important characteristics of the plantar skin.<sup>[17,18]</sup> The ideal technique for plantar forefoot reconstruction should provide a comfortable and durable weight-bearing surface, and allow the patient to ambulate in normal footwear.<sup>[19]</sup> However, it remains difficult and challenging for plastic surgeons to reconstruct the plantar forefoot, as the unique histological and weight-bearing properties of the forefoot is almost impossible to replace.<sup>[20]</sup> Now, no intensive study is performed on the reconstruction of plantar forefoot.

To achieve the reconstructive principle of replacing “like with like”, instep flaps from the non-weight-bearing instep area are still the popularity in small- to medium-sized soft tissue reconstruction of the plantar forefoot because of their simple surgical procedures and short operation time.<sup>[17,18,21]</sup> They can be elevated as pedicled flaps,<sup>[4,5,6]</sup> or free flaps,<sup>[22]</sup> and contain the same anatomical properties that are unique to the plantar skin. However, when local tissues are injured or when the defect of the plantar forefoot is extensive or is associated with complicated fractures or severe chronic infection, microsurgical free-tissue transfer should be considered as a requirement for limb salvage. In various free-tissue transfers, skin-grafted muscle flaps and fasciocutaneous flaps are the main reconstructive options.<sup>[23]</sup> Though there were some optimal results for free skin-grafted muscle flaps, functional impairment, high ulceration rates, and absence of sensation were not satisfactory.<sup>[23–25]</sup> On the other hand, free fasciocutaneous flaps, such as radial forearm flaps, could provide superior aesthetic results and neurotized tissue.<sup>[26]</sup> However, some disadvantages of these flaps have emerged, such

as significant donor site morbidity and flap instability resulting from high modulus of shear.<sup>[2]</sup> Therefore, the optimal reconstructive solution of the plantar forefoot is highly desired. To the best of our knowledge, this is the largest series of free ALT flap for reconstruction of plantar forefoot defects in the literature, which led to excellent functional and aesthetic outcomes.

Since the emergence of the ALT flap, it has served as an important technique to reconstruct various soft tissue defects, leading to superior functional, and aesthetic results.<sup>[16]</sup> Moreover, this flap is considered as a reliable and durable flap for the reconstruction of defects of ankle and foot.<sup>[14,15,27,28]</sup>

The ALT flap is described as a perforator flap in the literature, and it can be raised as a thin skin flap or elevated as a myocutaneous flap to obliterate dead space.<sup>[19]</sup> The main perforators of the ALT flap originate from the descending branch of the lateral circumflex femoral artery. Moreover, most of these perforators are observed to exit primarily within a 5-cm-diameter circle centered at the midpoint of the line between anterior superior iliac crest and the superolateral border of the patella.<sup>[29,30]</sup> In our series, the perforators of flaps were located preoperatively using a handheld Doppler probe, which has adequate sensitivity for perforator location in our experience.

The main advantage of the ALT flap for the reconstruction of massive defects of the plantar forefoot is its versatility in design. We feel that a well-cushioned reconstruction is necessary to prevent breakdown over the underlying weight-bearing zones and allow the patient to walk barefoot without special shoes. In addition, Hollenbeck et al found that thinned flaps could be at increased risk of breakdown with respect to the weight-bearing subunits of the foot.<sup>[31]</sup> Saint-Cyr et al also argued that primary thinning should not be carried out in the extended ALT flap elevating so as to avoid flap failure.<sup>[32]</sup> Based on these reasons, primary thinning was not performed in all of the flaps in our study, and all flaps survived well. However, secondary flap

thinning may be required after the reconstructive surgery, which is the disadvantage of our study. In our series, 5 patients underwent the debulking procedures, and the final functional and aesthetic results of flaps were satisfactory.

Vacuum-assisted closure was performed for acute wounds in our series, which was not only a treatment for a wound, but also offered a bridge for a safe reconstruction surgery in a more stable patient.<sup>[33]</sup> Appropriate antibiotics were administered concomitantly. When the wounds were clear and no significant inflammatory and necrotic tissues existed, the reconstructive procedures were performed. All of the flaps survived well, and there was no infection in the wounds perioperatively.

To reduce risk of thrombosis of recipient vessels during the free flap transfer, microvascular anastomosis should be performed outside of the injured zones.<sup>[28]</sup> Furthermore, recipient vessel selection is also vital to avoid free flap failure.<sup>[34]</sup> Many authors suggested that the venous return of flap was maintained well with only 1 accompanying vein anastomosis.<sup>[35,36]</sup> In our cases, since the ALT flaps were large, the 2 recipient veins, including great saphenous vein and an accompanying vein of the artery, were chosen for anastomosis to avoid congestion of the flap and postoperative complications. No flap congestion occurred postoperatively using this anastomosis method in our series.

No serious postoperative complications occurred in our cases. The donor site was directly closed or repaired using FTSG. Skin grafting the donor site has some complications, which are generally associated with pitting shape, worse scarring, numbness and a higher rate of limitation in the knee range of motion. It was reported that an anteromedial thigh perforator flap could be used to repair the ALT free flap donor site, resulting in the good appearance of the donor site and avoiding the limitation of activities of the knee.<sup>[37,38]</sup> Therefore, this anteromedial thigh perforator flap can be used as an alternative to skin grafting. Though the donor site scar appeared on the anterolateral thigh in our study, this was considered acceptable and negligible when compared with salvage reconstruction of the plantar forefoot. Some serious organic diseases, such as diabetes, may affect the hemodynamics of the distal limbs and cause poor blood microcirculation, which may lead to the decline of flap survival rate. Despite various advantages of this flap, this study has some limitations, such as the relatively small number of patients and the lack of investigation on sensory nerve coaptation of the ALT flap. Previous studies have highlighted the fact that there was no significant difference among flaps with or without sensory nerve coaptation regarding sensory recovery and postoperative ulceration rate.<sup>[2,19,24,39]</sup> In this study, the sensory nerve reconstruction of all flaps was not performed. However, of note is the fact that the sensory recovery in our study was achieved at 12 months postoperatively, which was sufficient to maintain the soft-tissue stability of flaps. Moreover, during the follow-up period, no patient was afflicted by ulceration on the weight-bearing zones of all flaps.

## 6. Conclusion

In conclusion, in the soft-tissue reconstruction of the plantar forefoot, including the weight-bearing surfaces, each patient should be evaluated individually. An ALT flap can be used to reconstruct quite extensive defects of the plantar forefoot, and even total plantar loss, leading to excellent functional and aesthetic results. Therefore, reconstruction of the plantar forefoot

region using an ALT flap is thought to be a satisfactory and valuable option.

## Author contributions

**Conceptualization:** Yang Liu.

**Investigation:** Lei Chen.

**Methodology:** Zhigang Liu.

**Resources:** Zhixin Zhang.

**Supervision:** Ruijun Li.

**Writing – original draft:** Lei Chen, Yang Liu.

**Writing – review & editing:** Yang Liu.

## References

- [1] Hills AP, Hennig EM, McDonald M, et al. Plantar pressure differences between obese and non-obese adults: a biomechanical analysis. *Int J Obes Relat Metab Disord* 2001;25:1674–9.
- [2] Santanelli F, Tenna S, Pace A, et al. Free flap reconstruction of the sole of the foot with or without sensory nerve coaptation. *Plast Reconstr Surg* 2002;109:2314–22.
- [3] Hirsch G, McBride ME, Murray DD, et al. Chopart prosthesis and semirigid foot orthosis in traumatic forefoot amputation. Comparative gait analysis. *Am J Phys Med Rehabil* 1996;75:283–91.
- [4] Baker GL, Newton ED, Franklin JD. Fasciocutaneous island flap based on the medial plantar artery: clinical applications for leg, ankle, and forefoot. *Plast Reconstr Surg* 1990;85:47–58.
- [5] Bhandari PS, Sobti C. Reverse flow instep island flap. *Plast Reconstr Surg* 1999;103:1986–9.
- [6] Butler CE, Chevray P. Retrograde-flow medial plantar island flap reconstruction of distal forefoot, toe, and webspace defects. *Ann Plast Surg* 2002;49:196–201.
- [7] Hallock GG, Rice DC, Keblish PA, et al. Restoration of the foot using radial forearm flap. *Ann Plast Surg* 1988;20:14–25.
- [8] Rainer C, Schwabegger AH, Bauer T, et al. Free flap reconstruction of the foot. *Ann Plast Surg* 1999;42:595–606.
- [9] Kuran I, Turgut G, Bas L, et al. Comparison between sensitive and nonsensitive free flaps in reconstruction of the heel and plantar area. *Plast Reconstr Surg* 2000;105:574–80.
- [10] Colen LB. Limb salvage in the patient with severe peripheral vascular disease: the role of microsurgical free-tissue transfer. *Plast Reconstr Surg* 1987;79:389–95.
- [11] May JW Jr, Gallico GG 3rd, Jupiter J, et al. Free latissimus dorsi muscle flap with skin graft for treatment of traumatic chronic bony wounds. *Plast Reconstr Surg* 1984;73:641–51.
- [12] Ferreira MC, Besteiro JM, Monteiro AA, et al. Reconstruction of the foot with microvascular free flaps. *Microsurgery* 1994;15:33–6.
- [13] Song YG, Chen GZ, Song YL. The free thigh flap: a new free flap concept based on the septocutaneous artery. *Br J Plast Surg* 1984;37:149–59.
- [14] Hong JP. Reconstruction of the diabetic foot using the anterolateral thigh perforator flap. *Plast Reconstr Surg* 2006;117:1599–608.
- [15] Kuo YR, Seng-Feng J, Kuo FM, et al. Versatility of the free anterolateral thigh flap for reconstruction of soft-tissue defects: review of 140 cases. *Ann Plast Surg* 2002;48:161–6.
- [16] Wei FC, Jain V, Celik N, et al. Have we found an ideal soft-tissue flap? An experience with 672 anterolateral thigh flaps. *Plast Reconstr Surg* 2002;109:2219–26.
- [17] Löfstrand JG, Lin CH. Reconstruction of defects in the weight-bearing plantar area using the innervated free medial plantar (instep) flap. *Ann Plast Surg* 2018;80:245–51.
- [18] Scheufler O, Kalbermatten D, Pierer G. Instep free flap for plantar soft tissue reconstruction: indications and options. *Microsurgery* 2007;27:174–80.
- [19] Hong JP, Kim EK. Sole reconstruction using anterolateral thigh perforator free flaps. *Plast Reconstr Surg* 2007;119:186–93.
- [20] Pappalardo M, Jeng SF, Sadigh PL, et al. Versatility of the free anterolateral thigh flap in the reconstruction of large defects of the weight-bearing foot: a single-center experience with 20 consecutive cases. *J Reconstr Microsurg* 2016;32:562–70.
- [21] Liebau J, Berger A, Pallua N, et al. Reconstruction of plantar defects. *Eur J Plast Surg* 1997;20:300–5.

- [22] Acikel C, Celikoz B, Yuksel F, et al. Various applications of the medial plantar flap to cover the defects of the plantar foot, posterior heel, and ankle. *Ann Plast Surg* 2003;50:498–503.
- [23] Sönmez A, Bayramiçli M, Sönmez B, et al. Reconstruction of the weight-bearing surface of the foot with nonneurosensory free flaps. *Plast Reconstr Surg* 2003;111:2230–6.
- [24] May JW Jr, Halls MJ, Simon SR. Free microvascular muscle flaps with skin graft reconstruction of extensive defects of the foot: a clinical and gait analysis study. *Plast Reconstr Surg* 1985;75:627–41.
- [25] Ohjimi H, Taniguchi Y, Kawano K, et al. A comparison of thinning and conventional free-flap transfers to the lower extremity. *Plast Reconstr Surg* 2000;105:558–66.
- [26] Musharafieh R, Atiyeh B, Macari G, et al. Radial forearm fasciocutaneous free-tissue transfer in ankle and foot reconstruction: review of 17 cases. *J Reconstr Microsurg* 2001;17:147–50.
- [27] Hu R, Ren YJ, Yan L, et al. A free anterolateral thigh flap and iliotibial band for reconstruction of soft tissue defects at children's feet and ankles. *Injury* 2015;46:2019–23.
- [28] Baumeister S, Radu CA. Salvage reconstruction of the severely traumatized foot and ankle. *Tech Orthop* 2009;24:96–107.
- [29] El-Gammal TA, El-Sayed A, Kotb MM, et al. Dorsal foot resurfacing using free anterolateral thigh (ALT) flap in children. *Microsurgery* 2013;33:259–64.
- [30] Liu L, Cao X, Zou L, et al. Extended anterolateral thigh flaps for reconstruction of extensive defects of the foot and ankle. *PLoS One* 2013;8:e83696.
- [31] Hollenbeck ST, Woo S, Komatsu I, et al. Longitudinal outcomes and application of the subunit principle to 165 foot and ankle free tissue transfers. *Plast Reconstr Surg* 2010;125:924–34.
- [32] Saint-Cyr M, Schaverien M, Wong C, et al. The extended anterolateral thigh flap: anatomical basis and clinical experience. *Plast Reconstr Surg* 2009;123:1245–55.
- [33] Argenta LC, Morykwas MJ, Marks MW, et al. Vacuum-assisted closure: state of clinic art. *Plast Reconstr Surg* 2006;117(Suppl 7):127S–42S.
- [34] Baumeister S, Follmar KE, Zenn MR, et al. Strategy for reoperative free flaps after failure of a first flap. *Plast Reconstr Surg* 2008;122:962–71.
- [35] Kimata Y, Uchiyama K, Ebihara S, et al. Anatomic variations and technical problems of the anterolateral thigh flap: a report of 74 cases. *Plast Reconstr Surg* 1998;102:1517–23.
- [36] Demirtas Y, Neimetzade T, Kelahmetoglu O, et al. Free anterolateral thigh flap for reconstruction of car tire injuries of children's feet. *Foot Ankle Int* 2010;31:47–52.
- [37] Visconti G, Salgarello M. Anteromedial thigh perforator-assisted closure of the anterolateral thigh free flap donor site. *J Plast Reconstr Aesthet Surg* 2013;66:e189–92.
- [38] Zhou X, Wang J, Qiang L, et al. Outcomes of using a modified anteromedial thigh perforator flap for repairing the anterolateral thigh free flap donor site: a retrospective clinical review. *Medicine* 2018;97:e0491.
- [39] Potparić Z, Rajacić N. Long-term results of weight-bearing foot reconstruction with non-innervated and reinnervated free flaps. *Br J Plast Surg* 1997;50:176–81.