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Original Article

Functional and Aesthetic Outcomes of Reconstruction of Soft-Tissue Defects of the Heel with Free Flap

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ABSTRACT

Objective: To evaluate functional and aesthetic outcomes of the reconstruction of soft-tissue defects of the heel with microsurgical techniques using a free radial forearm flap and an anterolateral thigh flap.

Patients and methods: The study included 25 patients, 15 males and 10 females, with a mean age of 34.3 ± 10.4 years, with soft-tissue defects of the heel. Of them, 11 patients whose defects were of size between 5 and 10 cm in their largest dimension were treated using a free radial forearm flap, and 14 patients whose defects were of size larger than 10 cm in their largest dimension were treated using a free anterolateral thigh flap.

Post-operatively, avoidance of weight-bearing and walking was required for 8 to 10 weeks. At the end of the follow-up, all patients underwent functional, aesthetic and sensation evaluation in addition to assessment of patient satisfaction.

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Results: The median follow-up period was 24 months. The causes of the defect were trauma (14 patients), neuropathic ulcer (8 patients) and neoplasia (3 patients). The size of the defect ranged from 5×6 cm to 14×24 cm. Four patients had calcaneal fracture. By the end of the follow-up period, 21 cases showed complete success, whereas 2 flaps failed, one in each flap type, and the remaining two flaps showed partial loss of the edges (anterolateral thigh flaps). Failure was due to venous congestion (one patient) and ischaemia (one patient). Eighteen patients were satisfied with their aesthetic appearance, functional outcome and flap sensation.
Conclusion: Reconstruction of large heel defects, using radial forearm and anterolateral thigh free flaps, provides acceptable functional and aesthetic outcomes.

Introduction

Reconstruction of heel defects still represents a surgical challenge that often requires high surgical expertise.[1] The anatomical and functional characteristics of this weight-bearing region complicate the surgical options for management. The thick, glabrous sole skin is a crucial problem when replaced by dissimilar skin from distant sites. However, several reconstructive options have been described, including skin grafts, local advancement flaps, cross-leg flaps, island pedicle flaps and microsurgical free flaps.[2] Each of these procedures has advantages and disadvantages without entirely satisfactory results.[3]

The choice of the flap depends on many factors such as the patient's age, defect size, skin characteristics, adequacy of arterial supply for the reconstructive needs and donor site morbidity. Flap modalities available for reconstructing heel defects include local flaps, island flaps, local muscle flaps, reversed fasciocutaneous flaps and free flaps with microvascular anastomosis.[2]

Free flaps are considered for extensive defects or if no local flap can be harvested with safety. For moderate defects, a radial artery forearm flap, a parascapular medial arm flap and so on are used. For larger defects, an anterolateral thigh (ALT) flap is used.[4] Microsurgical reconstruction has been established as the gold standard for the treatment of complex soft-tissue defects in the lower extremities.[5]

In this article, we present the experience of the authors' group in the reconstruction of soft-tissue defects of the heel using free flaps with microsurgical techniques; two types of flaps were used: the radial forearm flap (RFF) and the anterolateral thigh flap (ALTF).

Patients and Methods

The current study was conducted in the General Surgery Department of Benha University Hospital after obtaining approval from the local ethical committee and after fully informed written consent was signed by the patient. This study was carried out on 25 consecutive patients with soft-tissue defects of the heel, from January 2014 to December 2017, including the follow-up period (24 months).

Inclusion criteria were as follows: (1) soft-tissue defects localised to the heel with or without grade I or II calcaneal fracture, according to Sanders classification; (2) stable ankle joint; (3) intact both anterior and posterior tibial arteries as ensured clinically and by duplex and computed tomography (CT) angiography and (4) absence of significant comorbidities (cardiopulmonary problems and advanced liver or renal diseases).

Exclusion criteria included the following: (1) major lacerations of ankle joint or lower 1/3 of the leg that may affect distal vascularity; (2) significant atherosclerotic anterior or posterior tibial arteries detected by CT angiography; (3) poorly controlled or long-standing diabetes mellitus; (4) generally unfit patient for major surgery; (5) locally advanced malignancy that needs amputation or inguinal lymphadenectomy, or metastatic disease; (6) congenital malformation or chronic lymphatic obstruction of the affected limb and (7) mangled limb.

Of the 25 patients, 11 patients were treated by free RFF and 14 were treated by free ALTF. RFF was performed on patients whose defects were of size between 5 and 10 cm in the largest dimension. The flap was elevated from the non-dominant forearm. ALTF was performed for defects of size larger than 10 cm in the largest dimension. The flap was elevated from an uninjured limb.

Surgical procedure

Wound preparation before reconstructive surgery

1. For neoplastic cases, wide excision of the tumour with a wide safety margin and frozen-section histopathological examination was performed to confirm that the margin was free from tumour cells. Next, the size of the defect was measured (Figure 1).
2. For calcaneal fracture cases, debridement of bone fragments was performed.
3. For post-traumatic and neuropathic skin necrosis cases, wide excision of the non-viable tissue was performed, and the size of the defect was measured (Figure 2).

Step 1: Preparation

Preparation of the raw area includes debridement, curettage and micro-dissection of the recipient vessel. The recipient vessels are dissected under the operating microscope to separate the artery from the two venae comitantes for a distance of 2–3 cm (for easy anastomosis). The recipient vessel is either the anterior tibial artery and its vena comitantes or the posterior tibial artery with its vena comitantes. Division of the vessel is postponed after flap elevation. Nerve anastomosis is performed with either the calcaneal branch of the posterior tibial nerve or the medial dorsal cutaneous nerve of the superficial peroneal nerve.

Step 2: Flap elevation

The flap to be used is elevated according to the known standard technique. The deep fascia is elevated with the flap (fasciocutaneous flaps). In cases of a free RFF, the radial vascular bundle is elevated together with the cephalic vein as an extra venous drainage and the lateral ante-brachial cutaneous nerve for sensory supply of the flap (Figure 2). In cases of an ALTF, the perforator is dissected to the descending branch less frequently to transverse the branch and then to the main trunk of the circumflex femoral artery depending on the lateral femoral cutaneous nerve for sensory supply. Dimensions of the flaps are determined according to the size of the defect (Figure 1).

Step 3: Flap transfer

The recipient vessels are divided with Oakland closure of the proximal ends and ligation of the distal ends, and then the two ends of both recipient and flap vessels are placed under the operating microscope to start the anastomosis of the artery, first using Prolene 8/0 interrupted suture (usually eight sutures) followed by anastomosis of the venae comitantes, using 9/0 interrupted sutures (usually six sutures). All vascular anastomosis is performed end to end except in patients with diabetes, when it is usually performed side to end. The nerve anastomosis is performed with 8/0 Prolene interrupted sutures end to end.

The anastomosis fixation of the flap to the recipient area is completed using 3/0 interrupted Monocryl sutures with subcutaneous suction drain 16 F.

Study outcome

A) **Surgical outcomes**

- Intraoperative (IO) data included operative time, IO blood loss and frequency of IO complications.
- Post-operative (PO) data included PO hospital stay and frequency of PO complications.

Figure 1. Anterolateral thigh flap.

B) **Functional outcomes**

- PO follow-up extended for 24 months. The functional outcome was assessed at 6, 12, 18 and 24 months PO. Evaluation included patient satisfaction and aesthetic outcome and static 2-point discrimination (s2PD) test using an odd-leg calliper; a revised foot function index was used to evaluate functional difficulty.

The revised foot function index score has five subscales for evaluation:

(1) Foot pain (a score of 10 means no pain and a score of 40 means severe pain).

Figure 2. Free radial forearm flap.

(2) Foot stiffness (a score of 8 means no foot stiffness and a score of 32 denotes maximum foot stiffness).
(3) Difficulty in using foot (a score of 20 means no difficulty and 80 means severe difficulty).
(4) Activity limitation (a score of 4 denotes no activity limitation and a score of 16 means severe activity limitation).
(5) Social issues (a score of 19 means no limitation of social activity and a score of 76 means marked limitation of the patient's social activity).

An index is calculated by summing responses and dividing by the maximum possible score on each subscale to obtain separate percentage scores for each.

Score interpretation: range of 25–100% on each subscale, plus an overall percentage score. Higher scores indicate worsening foot health and poorer foot-related quality of life.

Table 1
Patients' characteristics.

	Number	Percentage
Working activity		
Manual worker	13	52%
Employee	6	24%
Student	3	12%
House wife	3	12%
Concomitant disease		
None	14	56%
Diabetes mellitus	8	32%
Viral hepatitis C	3	12%
Side of lesion		
Right	15	60%
Left	10	40%
Aetiology		
Trauma	14	56%
Neuropathic	8	32%
Neoplasia	3	12%
Recipient site condition		
Tissue loss with granulation tissue	13	42%
Gangrenous soft tissue	4	16%
Necrotic tissue	5	20%
Malignant ulcer	2	8%
Residual malignancy	1	4%
Associated calcaneal fracture	4	16%
Type of flap		
Anterolateral thigh	14	56%
Radial forearm	11	44%

Statistical analysis

Obtained data were presented as mean ±SD, median, interquartile range (IQR), numbers, and percentages. Results were analysed using Mann–Whitney U and Wilcoxon tests. Statistical analysis was conducted using SPSS (version 20, 2006) for Windows statistical package. P value <0.05 was considered statistically significant.

Results

The study included 25 patients, 15 males and 10 females, with a mean age of 34.3 ± 10.4 years (range: 15–50 years). The mean body mass index was 30.5 ± 3.8 kg/m^2. The cause of the defect was mainly post-traumatic tissue loss (n = 14), neuropathic ulcer due to diabetes mellitus (n = 8) and neoplasia (n = 3). The neoplastic cases included two cases of verrucous carcinoma and one case of Marjolin's ulcer.

The size of the defect ranged from 5 × 6 cm to 14 × 24 cm. The mean largest diameter was 11.8 ± 4.0 cm, and the mean depth of the lesion after debridement was 1.9 ± 0.7 cm.

No cases were associated with neurovascular damage (Table 1).

Eleven patients underwent RFF with an average operation time of 360 ± 25 min and blood loss of 450 ± 40 ml with no need for blood transfusion or ICU admission and average hospital stay of approximately 12 ± 3 days. The remaining 14 patients who underwent ALTF needed more operation time (average 480 ± 18 min) and sustained more blood loss (average 1200 ± 60 ml of blood), which necessitated blood transfusion in two cases, and a longer hospital stay (average 18 ± 5 days). These differences are due to the larger size of the ALTF, more meticulous dissection needed for its elevation and greater complexity of the defect requiring coverage (Table 2).

By the end of the follow-up period, 21 cases showed complete success and two flaps failed, one in each flap type, and the remaining two flaps showed partial loss of the edges (ALT flaps). The cause of failure was venous congestion (one case) and ischaemia (one case), whereas ischaemia of the edges

Table 2
Operative and post-operative data.

	RFF	ALTF
No. of patients	11 (44%)	14 (56%)
Op time	360 ± 25 min	480 ± 18 min
Op blood loss	450 ± 40 ml	1200 ± 60 ml
Need for blood transfusion	———	2 cases (8%)
ICU admission	———	———-
Hospital stay	12 ± 3 days	18 ± 5 days

Table 3
Post-operative complications.

Complication	RFF (25)	ALTF (25)
Total flap loss	1 (4.0)	1 (4.0)
Partial flap loss	0 (0.0)	2 (8.0)
Bulky flaps	0 (0.0)	10 (40.0)
Flap ulceration	1 (4.0)	2 (8.0)
Infection	2 (8.0)	4 (16.0)
Seroma	0 (0.0)	0 (0.0)
Haematoma	0 (0.0)	1 (4.0)
Absent flap sensation	2 (8.0)	3 (12.0)
Patchy sensory loss	1 (4.0)	5 (20.0)
Donor site morbidity		
*hypertrophic scar	1 (4.0)	2 (8.0)
*keloid	0 (0.0)	0 (0.0)
*hyperpigmentation	1 (4.0)	0 (0.0)
*contracture	0 (0.0)	0 (0.0)

was the cause of partial flap loss. The lost portion of the flap was treated with repeated dressing and healed in 4 weeks by secondary intention. Bulky flaps occurred in 10 of the ALTF cases, especially in the large-dimension cases; four of these cases underwent debulking after 18 months. The remaining six cases refused any other intervention. Flap ulceration occurred in three cases of the lost-sensation flaps, which was treated conservatively and by wearing special shoes. Infection occurred in six cases, especially in diabetic cases and post-traumatic cases, and was treated conservatively. Haematoma occurred in one case of ALTF, which was caused by oozing from the debrided recipient site and treated by reoperation, evacuation and proper haemostasis. Flap sensation was absent in five cases, and patchy sensory loss occurred in another six cases. Diabetic cases were usually affected with disturbed sensory function. The donor sites were closed by a split-thickness graft after 2 weeks until the muscle of the donor area became covered with the granulation tissue, with one case showing hyperpigmentation and three cases developing hypertrophic scarring, treated with silicon-containing gel (Table 3).

The s2PD test was used to detect how finely the flap was innervated and to detect the reduced sensory perception in the flap. The 2PD test result was usually negative during the first 6 months and improved gradually during the follow-up period, with no statistically significant difference between both types of flaps, but the values were usually more than those for the normal foot. There were five cases with totally absent flap sensation and another six cases with patchy sensory loss due to diabetes and incomplete nerve recovery. Patchy sensory loss occurred in large-sized flaps (five cases of ALTF and one case of a large RFF) (Table 4).

Eighteen patients were satisfied with the aesthetic appearance. The main causes of patient dissatisfaction were bulky flaps, inability to wear normal footwear and sensory loss (Table 5).

The revised foot function index (FFI) score was always higher with ALTF than with RFF, and this was assumed in larger and complex defects covered by an ALTF. In addition, the donor site is in a lower limb, which adds difficulty in rapidly returning to normal activity.

At the end of the follow-up period, the total revised FFI for both types of flaps reached near normal, with 4.33% higher for the RFF and 9% higher for the ALTF (Table 6).

Table 4
Mean 2PD at the flap during the follow-up period.

	Type of flap	6 months	12 months	18 months	24 months
2PD	RFF (11)				
	Mean ± SD	4.15 ± 0.98	3.66 ± 0.59	3.35 ± 0.61	3.21 ± 0.56[a]
	Median, IQR	4.8, 3–5	4, 3–4.2	3, 2.8–4	3.5, 2.6–3.6
	ALTF (14)	3.56 ± 0.75*	3.15 ± 0.52*	2.97 ± 0.50[a]	2.9 ± 0.49[a]
	Mean ± SD	3.5, 2.8–4.3	3.16, 2.66–3.65	2.8, 2.5–3.43	2.6, 2.5–3.43
	Median, IQR				

Table 5
Patients' satisfaction and aesthetic outcomes.

Patient's satisfaction	Very satisfied	Satisfied	Poorly satisfied	Unsatisfied
No. of patients	––––––	18 (72%)	2 (8%)	5 (20%)
Aesthetic outcome	Excellent	Good	Fair	Poor
No. of patients	8 (32%)	10 (40%)	3 (12%)	4 (16%)

Table 6
Revised FFI score repeated every 6 months for 2 years during the follow-up period.

	Type of flap	6 months	12 months	18 months	24 months
Pain score %	RFF (11)	56.55±6.42	43.45±4.08[a]	34.45±5.18[ab]	29.73±3.23[abc]
	Mean±SD	60, 49-62	45, 39-47	31, 30-40	28, 27-33
	Median, IQR				
	ALTF (14)	70.93±7.17**	61.54±5.99[a]*	48.07±5.22[ab]*	32.86±2.92[abc]*
	Mean±SD	76, 63-77	57, 56.5-68.5	51.5, 42.38-52.6	34.5, 29.5-35.5
	Median, IQR				
Stiffness score %	RFF (11)	78.84±6.38	60.91±3.44[a]	38.26±4.31[ab]	28.29±5.03[abc]
	Mean±SD	83, 72.12-85	59, 58.5-66	41, 34-42.4	31, 23.12-33
	Median, IQR				
	ALTF (14)	80.22±5.4	64.98±4.17[a]*	43.87±5.24[ab]	34.31±2.85[abc]*
	Mean±SD	80.4, 74.75-85.2	62, 61.38-69.5	44, 38.88-49	33.5, 31.85-37.4
	Median, IQR				
Difficulty score %	RFF (11)	60.36±4.43	48.38±5.33[a]	32.64±2.99[ab]	27.14±2.66[abc]
	Mean±SD	63, 56-64	44.2, 43.7-54	34, 29.5-35.5	27.5, 24.5-30
	Median, IQR				
	ALTF (14)	68.93±4.70**	50.29±5.99[a]	38.69±4.31[ab]*	31.43±5.28[abc]
	Mean±SD	69, 64-73.25	50.5, 44.75-56	38.5, 34.58-42.9	31.5, 26.28-36.5
	Median, IQR				
Activity limitation score %	RFF (11)	74.91±6.89	50.27±5.29[a]	37.45±3.95[ab]	31.65±4.41[abc]
	Mean±SD	72, 68-82	54, 45-55	36, 34-41.5	35, 27-35.5
	Median, IQR				
	ALTF (14)	81.26±5.90*	68.14±4.72[a]*	50.07±3.08[ab]*	43.27±2.11[abc]*
	Mean±SD	81.5, 75.23-87	65, 64-73.25	51, 47-53	42, 41.45-45.65
	Median, IQR				
Social score issue %	RFF (11)	68.47±4.01	51.36±3.14[a]	36.59±5.01[ab]	31.36±3.12[abc]
	Mean±SD	68.4, 64.5-72.5	53, 48-54	36.5, 31.5-41.5	29, 28.5-34.5
	Median, IQR				
	ALTF (14)	78.79±5.25**	67.5±5.26[a]*	47.47±6.24[ab]*	38.11±3.58[abc]*
	Mean±SD	78.75, 73.88-84	67.25, 62.75-73	47.5, 41.4-53.43	36, 35-42
	Median, IQR				
Overall score %	RFF (11)	67.46±6	51.18±4.92[a]	35.5±5.02[ab]	29.91±2.69[abc]
	Mean±SD	67.3, 61.5-73.5	54, 46-55	35.5, 30.5-40.5	30, 27.5-32
	Median, IQR				
	ALTF (14)	76.5±4.78**	62.57±5.4[a]*	45.93±5.96[ab]*	36.0±3.19[abc]*
	Mean±SD	79, 71-81	65.5, 57-67.25	45.75, 40-52	36, 32.88-39.13
	Median, IQR				

* Significance between two groups at $p \leq 0.05$
[a] Significance against 6 month follow-up at $p \leq 0.05$ in the same group
[b] Significance against 12 month follow-up at $p \leq 0.05$ in the same group
[c] Significance against 18 month follow-up at $p \leq 0.05$ in the same group

Discussion

Heel reconstruction remains a challenge for reconstructive surgeons and an area of debate of the ideal technique to be followed. Nevertheless, there is a consensus that reconstruction should resist sheer and pressure with adequate sensory quality. Owing to the unique nature of the sole skin, optimal function can be ideally achieved by using local tissues. Unfortunately, in most instances, we are confronted by large defects that cannot be managed with local tissue. Free flaps offer the best solution in this situation.

A free flap for reconstruction of the foot is by all means not a new technique; it has been used since the 1970s for the repair of a wide range of foot defects.[6–8]

The current study demonstrated desirable aesthetic and functional results of reconstruction of large heel defects by using the radial forearm and ALT free flaps. At the end of the follow-up, we achieved an 84% success rate. Flaps failed totally in 8% due to venous congestion and ischaemia.

Failure of RFF occurred in one patient with diabetes in the fifth decade with neuropathic ulcers. The second patient with an ALT flap was a young male working as a builder and had a calcaneal fracture in addition to the soft-tissue defect.

In a previous study, a micro-vascular RFF was used in 25 patients with soft-tissue defects of the foot and ankle; the weight-bearing surface of the foot was involved in eight patients. The flap was successful in 92% of cases. Recurrent ulceration occurred in two patients with diabetes with weight-bearing flaps. Of the eight patients with weight-bearing flaps, one was non-ambulatory, one had limited ambulation and another one had flap loss.[9]

RFF was reported to be successful in a series of 17 patients; it provided an aesthetically excellent, durable and stable weight-bearing plantar surface. It was used for relatively large defects similar to those in the current study. Flap complications included superficial infection and recurrent ulcerations.[10]

This kind of fasciocutaneous flap was found to be associated with significantly less pain and less ulceration than that with split-skin grafted muscle flaps for the reconstruction of weight-bearing surfaces of the foot. Both types of flaps were non-sensate, which indicated the superiority of fasciocutaneous flaps even if sensory protection was not considered.[11]

This was confirmed in a retrospective study that evaluated the long-term results of a free fasciocutaneous flap with and without sensory nerve reconstruction. Patients with sensory nerve reconstruction showed better sensibility during the first postoperative year. However, later on, progressive improvement of sensibility was observed in flaps without surgical nerve repair.[12]

Kuran et al. compared non-sensate muscle-free flaps and sensate fasciocutaneous flaps in the reconstruction of the heel and plantar area for a long follow-up period (2–14 years). Patients with non-sensate flaps had no difficulty in daily living activities. The total contact areas of the foot and pressure values of the reconstructed areas were comparable in the two groups.[13]

A more recent study reported experience on the use of different flaps for soft-tissue reconstruction of the foot and ankle; 31 patients had plantar heel defects. Free flaps were used in 164 cases, and free lateral arm flaps were used in 12 cases. The rate of total free flap loss was 4.9%.[14]

Sole reconstruction should be oriented functionally as well as aesthetically. To accomplish a successful reconstruction procedure, the sole should be supplied with a comfortable and durable weight-bearing surface with protective sensation. The radial forearm free flaps proved to be successful in attaining this aim. Several authors acknowledged the ALT flap as a reliable reconstructive method for soft-tissue defects of the foot and ankle. In fact, some investigators preferred adipocutaneous flaps as the ALT flap because it was associated with better aesthetic results and easier revision surgery.[15] ALT flap had the advantage of being adaptable to different clinical situations, including ankle and heel defects. Compared to the RFF, it has the additional advantage of reduced donor site morbidity.[16]

ALT perforator free flaps of 4.6 mm thickness were previously used to treat plantar soft-tissue defects in 69 patients. The authors reported satisfactory aesthetic and functional results in all except one case. Protective sensation was regained by 12 months.[17]

The use of radial forearm and ALT free flaps with the application of microsurgical techniques was favourable for the reconstruction of heel defects. It provided good to excellent results from aesthetic and functional aspects.

Authors' contribution to the submission

All authors contributed to the submission. The surgeons (Hussein Elgohary, Ahmed M. Nawar, Ahmed Zidan, Ahmed A. Shoulah and Mohamed T. Younes) contributed to the operations and follow-up of cases in addition to writing the paper.

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Informed consent/ethics

Informed consent was obtained from the patient in this study. This study has been approved by the Ethics Committee of Banha University Hospital.

Conflict of interest

None of the authors have any conflicts of interest to declare in relation to this article. No funds were used to perform this study.

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