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Role of perforator flaps in leg and foot reconstruction

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Summary

Introduction: Lower extremity wounds have always been a challenge for the reconstructive surgeons. Free perforator flaps are considered to be the best option for this problem but require the complexity of microsurgery. So, pedicled perforator flaps have emerged as an alternative option. Patients and methods: Prospective study was conducted in 40 patients with traumatic soft tissue defects in the leg and foot. The free flaps included the anterolateral thigh flap (ALT) and medial sural artery perforator flap (MSAP). In pedicled perforator flaps group, 10 cases were designed as propeller flaps while the other 10 flaps were designed as perforator plus flaps. Results: Free flaps were mainly used for large-sized defects; we had one case of partial flap loss and one case of complete flap necrosis. MSAP flap was the first option for coverage of large-sized defects on foot and ankle as it is a thin and pliable flap, while ALT flap was used for coverage of larger defects on the leg. Pedicled perforator flaps were used mainly for small to medium-sized defects, especially in the lower third of the leg; we had three cases of flap loss in propeller flap design while we had no cases of flap loss in perforator plus flap. Conclusion: Perforator flaps have become a reasonable solution for soft tissue defects of the lower extremity. Careful assessment of the dimensions, location, patient comorbidities, availability of surrounding soft tissue and presence of adequate perforators are mandatory for proper perforator flap selection.

Key words

perforator flap – propeller flap – perforator plus flap – anterolateral thigh flap – medial sural artery perforator flap

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Introduction

The evolving technology in trauma management today permits salvage of many severe lower extremity injuries previously even considered to be fatal [1].

Soft tissue defects in the lower extremity, especially in the distal third of the leg, have always been problematic cases to the reconstructive surgeons as the local flaps in this region are not reliable [2].

Taylor and Palmer defined the angiosome as a three-dimensional vascular region supplied by an artery and a vein through branches for all the tissue layers between the skin and the bone, and showed that between the angiosomes, there are multiple choked and true anastomotic arteries [3].

After this evolution, and as a result of the publications done by Koshima and Soeda [4] as well as Kroll and Rosenfield [5] in 1989 separately, the era of perforator flaps has started.

Perforator flaps are defined as the flaps where the source artery is deep and the vessel that carries blood to the skin passes through the overlying fascia that covers the muscles [6].

Patients and methods

This prospective study was conducted in 40 patients with traumatic soft tissue defects in the leg and foot with or without bone injury who were admitted in the Hand & Microsurgery Unit and the Plastic Surgery Department, Assiut University Hospital, Assiut University, between 9/2017 and 8/2019.

All polytraumatized patients with poor general condition and disturbance of conscious level were excluded from the study. Also, patients with chronic debilitating diseases e.g. chronic renal failure, liver failure, etc. were excluded from the study.

Detailed personal and medical histories were taken from every patient. Careful local examination for any vascular injury, neurological deficit, bone fracture, size of the defect, and the condition of surrounding soft tissues was done.

Surgical debridement with removal of all foreign bodies, necrotic muscle and dead bone with subsequent regular changes of dressing was done for heavily contaminated and major-sized wounds for successful control of infection, while surgical debridement with primary coverage was done for mild contaminated and small-sized wounds.

Skeletal stabilisation and repair of any vascular injury to the injured limb was achieved initially.

The type of flap was chosen according to the site and size of the defect, the

Fig. 1. A) Post-traumatic raw area at the lower third of the leg and dorsum of the foot.

Fig. 1. B) Anterolateral thigh flap elevation with one perforator.

Fig. 1. C) Postoperative follow-up showing a bulky flap.

Fig. 1. D) After second stage debulking.

state of surrounding perforators and condition of the surrounding tissues.

The free flaps used included the anterolateral thigh flap (ALT) (Fig. 1) and medial sural artery perforator flap (MSAP) (Fig. 2), while the pedicled flaps included posterior tibial artery perforator flap, peroneal artery perforator flap and anterior tibial artery perforator flap.

The operations were performed using magnification loupes (3.5–4.0×) and microsurgical instruments. An 8 MHz handheld ultrasound doppler was used to detect perforator vessels in the donor site area. After detection of the perforator, the flap was designed around the perforator (or the perforators in case of a free flap) according to the location and size of the defect.

In free perforator flaps, microvascular anastomosis was carried out under operating microscope for one artery and for one or two accompanying veins. After anastomosis, brisk bleeding from the margin was confirmed before the flap inset over the defect. We did not do thinning of the ALT flap as we are not familiar with this technique.

In pedicled perforator flaps, 10 cases were designed as a propeller flap (Fig. 3A), where complete release of the edges of the flap was done with rotation of the flap around the perforator from 90 to 180° (Fig. 3B, C), the other 10 flaps were designed as perforator plus flaps (Fig. 4A), where the base of the flap was not incised and kept in place.

A tourniquet was inflated without prior exsanguination; this facilitates identification of perforators as they remain congested with blood. An exploratory incision along the margin of the flap was made through the skin, subcutaneous tissue, deep fascia (subfascial approach) and the perforator vessel was directly visualized. The incision was always made from one side of the flap only to properly identify the perforator.

In propeller flaps, meticulous dissection was performed to the perforator with adequate release of any fascial strands around it (Fig. 3B) (to facilitate rotation of the flap without any kinking or constriction to the perforator in pedicled flaps) and dissection around the perforator in intermuscular (Fig. 2C) or intramuscular plane was done. After deflation of the tourniquet, hemostasis was performed and the viability of the flap was evaluated.

A negative suction drain was inserted under all the flaps (both free and pedicled perforator flaps).

The donor site was either covered with a split thickness skin graft harvested from the thigh or closed primarily according to the size.

Leg elevation, adequate hydration of the patient and maintenance of average blood pressure and temperature (to prevent spasm of the vessels) are critical for the first post-operative 48 hours.

Fig. 2. A) Post traumatic raw area at dorsum of the foot.

Fig. 2. B) Design of the medial sural artery perforator flap.

Fig. 2C. Flap elevation and intramuscular dissection for two perforators.

Fig. 2. D) Follow-up of the medial sural artery perforator flap.

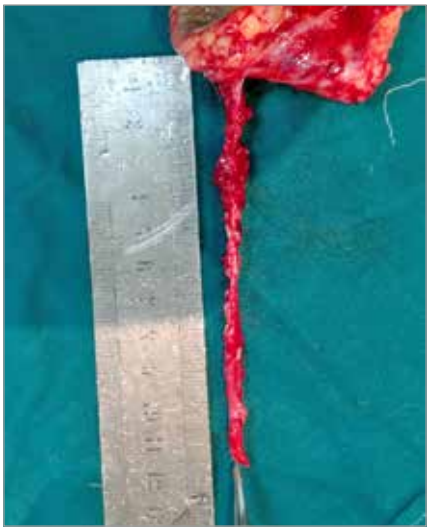


Fig. 2. E) Medial sural artery perforator with one perforator showing the pedicle's length up to 11cm (another case).

Fig. 2. F) Postoperative follow-up showing complete flap survival.

Clinical monitoring of the flap to detect intrinsic vascular problems (vasospasm) as well as extrinsic causes of perfusion compromise (hematoma, seroma, tight stitches due to subsequent edema and external pressure) is essential for the patient's successful outcome.

The flap was monitored each hour during the first 24 hours and every 2 hours for the next 24 hours.

Careful follow-up of the drain for any possible bleeding and hematoma formation, and removal of the drain was done when the content of the drain was serosanguinous and less than 30 cm^3 in 24 hours.

The first skin graft dressing change is usually performed on the 5th postoperative day and flap sutures are removed on the 14th postoperative day.

The follow-up was done after 1 week, 2 weeks and 1 month postoperatively.

The postoperative evaluation parameters were:

a) flap viability that was monitored with regards to color, temperature, capillary refill and congestion;
b) donor site morbidity;
c) overall esthetic appearance of the flap, which was evaluated by two plastic surgeons;
d) duration of hospital stay;
e) time to heal;

Fig. 3. A) Post-traumatic raw area and design of the posterior tibial artery propeller flap after detection of the perforator preoperatively.

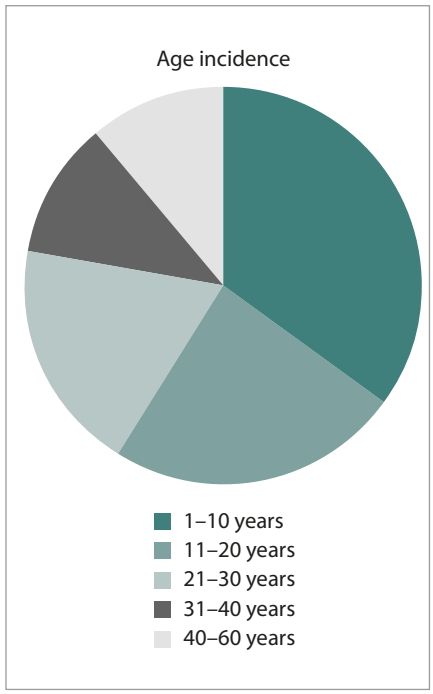
Fig. 3. B) Elevation of the flap with complete skeletonization of the perforator is mandatory for better flap survival with complete freeing of the edges of the flap.

Fig. 3. C) Postoperative follow-up, showing good flap survival and primary closure of the donor site.

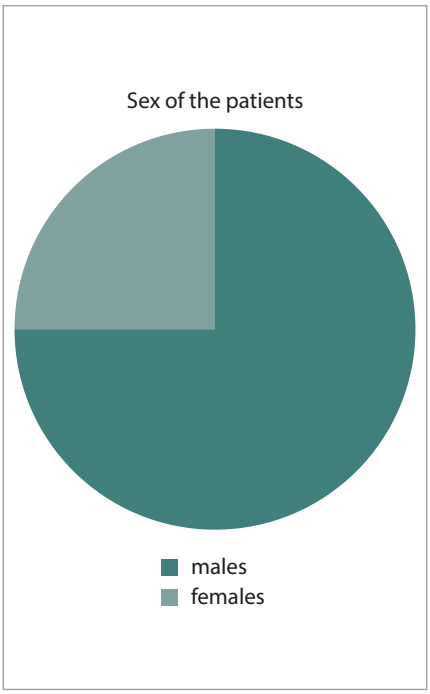
f) presence or absence of complications (partial or complete flap loss, dehiscence, seroma, hematoma and infection).

Statistical analysis

Our data are presented as the mean (± SD) or the median (range) in case of continuous data while nominal data are presented as frequency (percentage). No comparison was done, as the aim of the study was to detect the most suitable perforator flap for each defect according to its size and site; thus, no test was used.



Graph 1. Incidence by patient's age.



Graph 2. Incidence by patient's sex.

Results

The patients were divided into Group I and Group II. Group I included 20 patients who were treated with a free perforator flap, 14 patients were treated with ALT and 6 patients were treated with MSAP. Group II included 20 patients treated with pedicled perforator flap, 10 flaps were designed as propeller flaps while the other 10 flaps were designed as perforator plus flaps.

The age and the sex of the patients (patient demographics) are shown in Graphs 1 and 2.

The data of Group I (free perforator flap) and Group II (pedicled perforator flap) are presented in Tab. 1–3.

The results of Group I (ALT free flap) are shown in Fig. 1, the results of Group I (MSAP flap) in Fig 2., Group II

Fig. 4. A) Post-traumatic chronic ulcer at the lateral malleolus and design of the perforator plus flap.

Fig. 4. B) Complete isolation of the perforator and elevation of the peninsular fasciocutaneous flap.

Fig. 4. C) Postoperative follow-up showing good flap survival and closure of the defect by the split--thickness skin graft.

Fig. 4. D) Post-traumatic raw area at dorsum of the foot; elevation of the peroneal artery perforator plus flap length exceeds one third of the leg.

Fig. 4. E) A 5-day postoperative follow-up showing good viability of the flap with a dog ear deformity at the distal part of the flap.

Fig. 4. F) Second stage debulking.

(propeller flap) in Fig. 3 and Group II (perforator plus flap) in Fig. 4.

Discussion

Traumatic soft tissue loss of the lower limb is a common problem in young age (Graph 1), especially in males (Graph 2) in Upper Egypt. As we demonstrated in our study, the majority of patients (85%) were aged between 6 and 30 years

In our thesis, we decided to use ALT and MSAP flaps as they have a long pedicle that can be anastomosed away from the injury zone with the possibility of vessel anastomosis within and it also allows simultaneous approach, unlike other perforator flaps, e.g. scapular and thoracodorsal artery perforator (TDAP)

Tab. 1. Patient characteristics.

	Group I	Group II
Smoking	4	2
Sex		
– male	14	16
– female	6	4
Mechanism of trauma		
– road traffic accident	18	15
– post-traumatic chronic ulcer		
– post-traumatic contracture	1	3
– firearm injury	1	2
Size of the defects (range, cm)	11 × 5 to 33 × 16	3 × 4 cm to 11 × 6
Site of defects		
– foot dorsum only	6	5
– foot dorsum with lower third of foot	8	
– lower third only	3	11
– middle and upper thirds	2	4
– foot sole	1	

Tab. 2. Operative data.

	Group I	Group II
Duration of operation (hours)		
– average	6	1.5
– range	3–10	1–2.5
Type of flap		
– ALT	14	
– MSAP	6	
– posterior tibial artery perforator		10
– anterior tibial artery perforator		3
– peroneal artery perforator		7
Number of venous anastomosis		
– one	7	
– two	13	
Number of perforators		
– one	11	20
– two	9	
Type of ALT perforators		
– septocutaneous	3 (ALT)	17
– musculocutaneous	17 (11 ALT, 6 MSAP)	3 (peritoneal)

ALT – anterolateral thigh, MSAP – medial sural artery perforator

flaps. We did not use gracilis flap and SCIP flap as they are not perforator flaps and our study is about the evaluation of both free and pedicled perforator flaps in leg and foot reconstruction.

Besides the familiarity of the vascular anatomy of the ALT flap for most of the microsurgeons, the long and sizable vascular pedicle allows safe anastomosis away from the trauma zone [7].

The ALT flap is still considered the first choice especially for moderate or major-sized wounds for microsurgery as practiced in the United States [8], and the vascularity of this flap is robust and highly reliable [9], while the smaller wounds are treated with pedicled perforator flaps [10].

This is in accordance with our study as we demonstrated the size of defects in free flaps ranged between 11 × 5 cm and 33 × 16 cm (Fig. 1A) with majority in dorsum of the foot and lower third of the leg (85%) (Tab. 1), while in pedicled flaps the size of the defects ranged between 3 × 4 cm and 11 × 6 cm.

The ideal flap for the defects around the foot and ankle should be a thin and a pliable cutaneous flap with ideal tissue match [11].

The MSAP flap is a very versatile flap with almost constant anatomy. The advantages of this flap are: 1) preservation of the underlying gastrocnemius muscle; 2) thin and pliable flap; 3) the length of the pedicle may reach 8–10 cm; 4) quite sizable vessels which are approximately 1–3 mm; 5) if the flap is small-sized, the donor site can be closed primarily; and 6) it can be harvested while the patient is in a supine position [12].

As we demonstrated in our results, the ALT flaps usually need a second stage debulking (Fig. 1C, D), while the MSAP is a thin pliable perforator flap, with long pedicle up to 11 cm (Fig. 2E) so it is an excellent option for coverage of the defects on dorsum of the foot (Fig. 2A, D) and over the ankle joint (Fig. 2F).

In a study performed in 2010 by Hanason et al, it was shown that the blood velocity is reactively increased when one venous anastomosis is performed, because the low-velocity state increases the probability of thrombosis. This result was incompatible with the two venous anastomoses routinely done in free tissue transfer, and they are recommended when a technically adequate single venous anastomosis is done. The performance of a second venous anastomo-

sis unnecessarily increases the operative time [13].

In another study done by Heidekrueger et al in 2016, the authors concluded that a successful free tissue transfer for lower limb reconstruction could be achieved independently of the number of venous anastomoses, although when two venous anastomoses are technically available they should be performed [14].

In our study, there were 7 cases with one venous anastomosis (5 with the great saphenous vein, one with the anterior tibialis vein and one with the posterior tibialis vein (Tab. 2)) with no cases of venous congestion or partial flap loss. There were two cases of venous congestion with two venous anastomoses which were treated conservatively. We conclude that the results are the same in case of one or two vein anastomoses, and the great saphenous vein is a good option for single vein anastomosis.

We also consider the great saphenous vein as a reliable option for venous anastomosis with the condition that the patient does not have any venous disease.

A study done by Grover et al in 2014 on free deep inferior epigastric artery (DIEP) perforator flaps in breast reconstruction claimed that the number of the perforators has no impact on survival of free perforator flaps, although they said that the rate of fat necrosis may be higher in DIEP flaps based on one perforator, and they recommended usage of multiple perforators if possible, to decrease the risk of fat necrosis [15].

In our study we had 11 free flaps with one perforator (Fig. 1B, 2E), none of them were lost or even partially lost, so we concluded that there is also no difference in flap survival (whatever the length of the flap) regarding elevating the flap based on one or two perforators.

In all the cases with free flaps, the donor site was closed by skin graft except in one case (MSAP) where the width of the flap was 5 cm.

As we mentioned in our results, we used the pedicled flaps particularly for covering small to medium-sized defects in the distal third of the leg, Achilles tendon region and dorsum of the foot.

The main advantages of pedicled perforator flap were technically less demanding, because they are microsurgical procedures, but without microvascular sutures and with a shorter operating time [16].

In our study, there was a shorter operating time in pedicled perforator flaps (Tab. 2) (the median duration of the surgery was 1.5 hour with the range 1–2.5 hours) and a shorter hospital stay (the median time of the hospital stay was 4 days), compared with free flaps where the median operating time was 6 hours with the range of 3–10 hours, and the median hospital stay was 14 days, with subsequent saving of the resources and manpower.

In propeller flaps, meticulous dissection of the perforator is mandatory to prevent complications. All the muscular branches must be divided and the perforator must be cleared of all fascial strands for at least 2 cm, so the twist of the pedicle after rotation to the recipient site will be gentle and distributed over the entire length of the pedicle.

In a study from 2010, Maherota demonstrated that failure rates of pedicled perforator flaps can be significantly decreased with the use of the "perforator plus" concept in which the blood supply to a flap from a perforator is augmented by the blood supply from the flap base. This provides a dual blood

Tab. 3. Outcomes and complications.

	Group I		Group II	
Complete flap survival	18 12 (ALT) 6 (MSAP)		17 7 (propeller flaps) 10 (perforator plus flaps)	
Complications				
venous congestion	2 (1 ALT, 1 MSAP)		3 (propeller)	
partial flap loss	1 (MSAP)		1 (propeller)	
total flap loss	1 (ALT)		2 (propeller)	
infection & dehiscence	1		0	
hematoma or seroma	0		0	
Split-thickness skin graft over flap loss	1		3	
Donor site				
split-thickness skin graft	19		19	
closed primarily	1		1	
Duration of hospital stay (days)				
range	2–30		2–15	
average	14		4	
Duration of wound healing (days)				
range	10–30		10–21	
average	14		14	
Esthetic appearance of ALT	**ALT**	**MSAP**	**propeller**	**perforator plus**
acceptable	2	6	10	2
need for debulking	12	0	2	8

ALT – anterolateral thigh, MSAP – medial sural artery perforator

supply through the perforator and the subdermal plexus, and it also reinforces the venous drainage [17].

In our early experience, we had 3 cases of venous congestion (Tab. 3) with subsequent partial or complete flap loss in propeller flaps in which we noticed that the flap length was more than one third of the leg's length (from the head of the fibula to lateral malleolus), this was in accordance with the results of a study done by Panse et al in 2011, who claimed that the maximum safe length of the perforator propeller flap in leg is equal to or less than one third of the leg's length [18], while we had no cases of flap congestion or flap loss in perforator plus flaps regardless the length of the flap (Fig. 4A–F).

As a result of the above mentioned, we prefer to use a perforator plus flap in case the flap length exceeds one third of the leg length.

The only disadvantage of a perforator plus flap was that it needed another session for debulking the dog ear resulting from the peninsular movement of the flap (Fig. 4E, F), as we had 8 cases of perforator plus flaps which needed second stage debulking.

Conclusion

We can conclude our study with the following statements.

The ALT flap is considered the first choice, especially for moderate or major-sized wounds, while smaller wounds are treated by pedicled perforator flaps.

The MSAP is a thin pliable perforator flap with a pedicle long up to 11 cm, so it is an excellent option for coverage of the defects on the dorsum of the foot and over the ankle joint.

There is no difference in free perforator flap survival (whatever the length of the flap is) regarding elevating the flap based on one or two perforators.

Flap salvage is independent of the number of venous anastomosis, as the results are the same in case of one or two vein anastomosis, and the great saphenous vein is a good option for single vein anastomosis.

In pedicled perforator flaps, there was a shorter operating time and a shorter hospital stay compared with free flaps.

Regarding pedicled perforator flap, the use of the perforator plus flap in case the flap length exceeds one third of the leg length is a good option, although it needed another session for debulking the dog ear resulting from the peninsular movement of the flap.

Roles of authors:
Tarek A. EL-Gammal – principle investigator;
Youssef Saleh Hassan – principle investigator;
Tarek Raief – revision of scientific content of the manuscript;
Mohamed Elyounsi – date analysis and interpretation;
Mohamed Adel – writing (original draft).

Ethical approval: This work was conducted in accordance with the Code of Good Practice and the guidelines of Declaration of Helsinki and was approved by the Medical Ethics Committee of the Faculty of Medicine at Assiut University. Informed consent was obtained from each patient.

Conflict of interest: None.

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