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ORIGINAL ARTICLE
Reconstructive

Distally Based Sural Artery Peroneus Flap (DBSPF) for Foot and Ankle Reconstruction

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Background: Reconstruction of soft-tissue defects in lower third of leg, ankle, and foot has been a challenge and reconstructive surgeons have been trying to innovate different flaps. To solve this issue, we propose a distally based sural artery peroneus flap (DBSPF) in which we include superficial portion of the peroneus brevis muscle and its blood supply with the peroneal artery distally. The aim of this study was to evaluate the functional outcome and its usefulness over conventional distal sural artery flap or other local options available.

Methods: This is a case series of 20 patients that include a DBSPF that was done for defects around ankle, distal leg, and foot caused by trauma or tumor ablation within the period of June 2013 to March 2015 in Kasralainy Hospital, Cairo. All cases were evaluated according to flap vascularity, distal reach of flap, aesthetic outcome, and donor-site morbidity.

Results: All flaps survived. One flap developed venous congestion that subsided spontaneously with limb elevation. The flap dimension ranged from 42 cm to 442 cm^2, and it reached the midfoot easily. The pivot point was kept as low as 2–6 cm from lateral malleolus according to location of perforators. The ankle stability was maintained, and the desired aesthetic outcome was achieved.

Conclusions: The DBSPF is an addition to the armamentarium in plastic surgery for defects around ankle, distal leg, and foot. It is an easy and swift procedure as compared with complex microsurgical reconstruction. *(Plast Reconstr Surg Glob Open 2017;5:e1276; doi: 10.1097/GOX.0000000000001276; Published online 18 April 2017.)*

INTRODUCTION

Soft-tissue defects and complex wounds in the foot, the distal third of the leg, and ankle represent a great challenge for reconstructive surgeons.

Microvascular free flaps require arterial and/or venous anastomosis. In cases where microsurgery is not possible due to the lack of microsurgery expertise, equipment, or time, the distally based sural artery peroneus flap (DBSPF) can be a reliable, easier, and quicker option for the coverage.

The classic distally based sural flap, as described by Masquelet and Gilbert,[1] especially designed for the posterior aspect of the heel and the region of the lateral malleolus, includes a pedicle with the median sural artery in the proximal third of the calf (branch of popliteal artery) and the fasciocutaneous branches from the peroneal artery in the distal half of the leg, sural nerve, and small saphenous vein, which are sacrificed proximally.[2] The flap is outlined at the junction of the relief of the 2 heads of gastrocnemius, and the line of incision is traced over the presumed course of the sural nerve and small saphenous vein.

Although this flap provides a wide arc of rotation, a rapid coverage, and easy and quick elevation, the main disadvantages are the congestion due to poor venous drainage (if no small saphenous vein microanastomosis supercharging is done), sensory loss over the lateral aspect of the foot,[3] tension to close the donor site,[4] partial or total necrosis[5] due to the 180 degrees of rotation, the tunnelization, and the insufficient blood supply of the median sural arteries for the upper half of the posterior calf (if no gastrocnemius branch perforators are included), especially on medial malleolus (greater arc of rotation of flap and larger defects).[2]

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To overcome these problems, different flap modifications have been proposed, such as the distally based peroneus brevis muscle flap[4] and the distally based sural fasciomusculocutaneous flap with gastrocnemius muscle.[6–8]

In this article, we describe a DBSPF that includes a pedicle with median sural artery, sural nerve, and small saphenous vein, as well as the peroneal muscles with their blood supply, which includes branches from the peroneal artery, anterior tibial artery, and perforators from the posterior tibial artery.[2]

In this flap, foot inversion and eversion and plantar dorsiflexion as well as ankle stability are maintained due to preservation of the deeper muscle layers of the peroneus muscles.

The purpose of our study was to describe and evaluate a new flap, the DBSPF, which we nominate for foot and ankle defects, with an aim to know its viability, feasibility, and functional outcome.

MATERIALS AND METHODS

This descriptive retrospective study was conducted in Kasralainy Hospital from the period of June 2013 to March 2015 in 20 patients with soft-tissue defects with exposed bones, tendons, and other critical structures after trauma and tumor resection. Age groups were variable, ranging from 6 to 68 years. Total male to female ratio was 9:1. Defects were caused by trauma (n = 18) and tumor resection (n = 2). Inclusion criteria were patients with soft-tissue defects involving hind and midfoot with exposed bones or tendons that needed flap coverage. Exclusion criteria were peripheral vascular disease, severe crushing injury affecting vascularity of the foot or selectively affecting peroneal artery and its perforators. Hospital stay was for 24 hours with regular follow-up after discharge.

Routine preoperative evaluation included complete blood count and coagulation profile. Plain foot X-ray with different views was taken in trauma patients and those suspected to have osteomyelitis. All patients underwent handheld Doppler study to locate and mark the perforators of the peroneal artery close to the lateral malleolar region.

Patients were operated on under pneumatic tourniquet with regional and/or spinal anesthesia. General anesthesia was applied for children and in cases where spinal anaesthesia was contraindicated. Postoperatively, the patients were splinted in 100 degrees of plantar flexion to minimize tension on the flap and to decrease the shearing forces on the grafted donor site. Flap was monitored on a daily basis. The first dressing of the graft area was done on the fifth postoperative day. The splint was removed after 4 weeks of surgery, with simultaneous initiation of physiotherapy. Weight bearing on operated foot was started after 6 weeks of surgery, and patients were followed up for an average period of 6 months.

Surgical Technique

The flap was outlined as per defect after planning in reverse manner with proximal extent of flap approximately 4 fingerbreadths below the popliteal crease where the precise location of the skin paddle depended on the required length of the flap. All the flaps were of teardrop design with adipofascial pedicle (Fig. 1). Skin paddle was planned according to the defect. Skin island was narrowed down and continued until the pivot point (location of the first outlined perforator). This point was nearly 5–6 cm above lateral malleolus (Fig. 2). The flap was incised proximally down to the fascia covering the gastrocnemius muscle with inclusion of the sural nerve and short saphenous vein, which were ligated, dissected, and included within the flap. After incising the skin paddle on the medial and lateral sides, the dissection was carried

Fig. 1. Preoperative "teardrop" shape of the DBSPF.

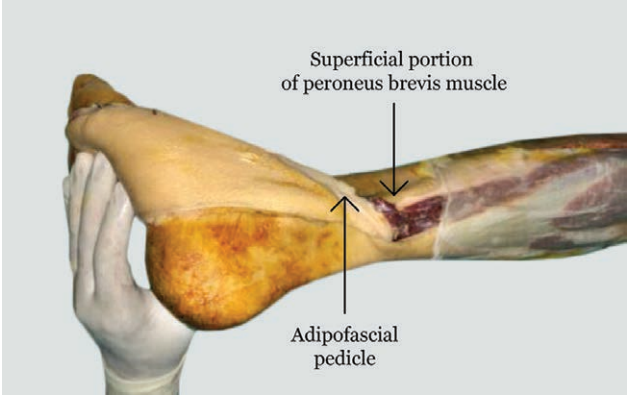

Fig. 2. Superficial portion of peroneus brevis muscle inclusion underneath the skin paddle.

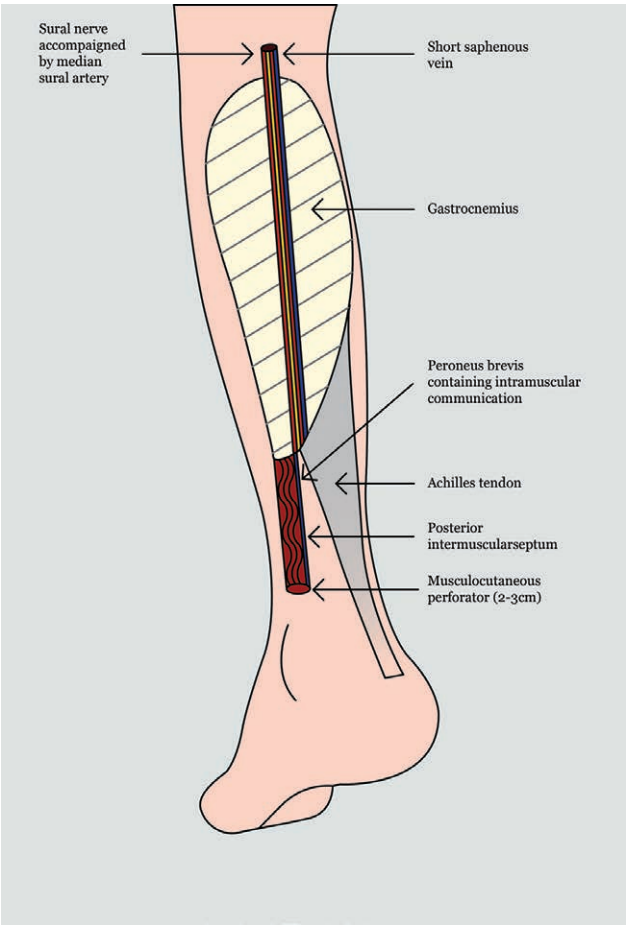

Fig. 3. Anatomical structures in the DBSPF dissection.

down until the level of the Achilles tendon. At this region, the tunnel was incised in an S-shaped manner, and subcutaneous undermining was done to mark the adipofascial pedicle while preserving the short saphenous vein, sural nerve along with the median sural artery (Fig. 3). The adipofascial pedicle was incised medially and dissection of the fasciocutaneous island and its adipofascial pedicle was carried out from medial to lateral until the location of the outlined perforators with the inclusion of posterior intermuscular septum. At this region, the median superficial sural artery ramifies into small branches that communicate with perforators of the peroneal artery (Fig. 4). They are initially septocutaneous and then they become musculocutaneous (as close as to lateral malleolus). In this study, we augmented the flap with inclusion of the superficial portions of the peroneus brevis muscle to preserve these ramifications that are continuous with the most distal musculocutaneous perforator (1–2 from the lateral malleolus) (Fig. 2). Thickness of the peroneus muscle was variable depending upon the ramification of the median sural artery. We dissected the ramifying branches of the median sural artery till its communication with the musculocutaneous perforator originating from the peroneal artery.

After raising the flap, it was sutured on to the recipient site after careful undermining of the tunnel skin to be closed without tension on the adipofascial pedicle. A suction drain was inserted underneath the flap, and donor site was covered with split-thickness skin graft.

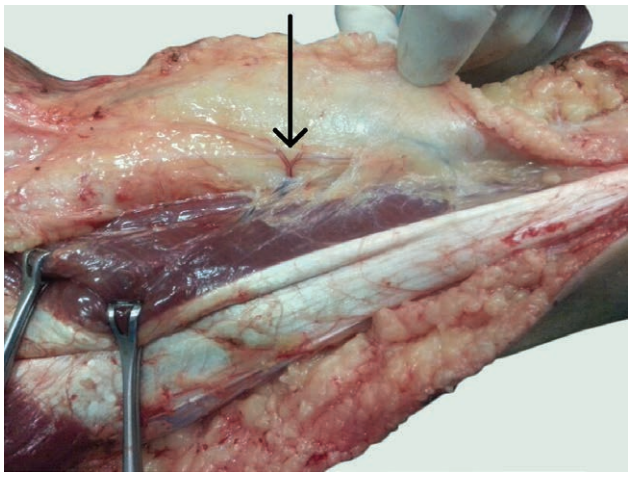

Fig. 4. Musculocutaneous perforator communication with the median superficial sural artery (arrow).

RESULTS

Soft-tissue reconstructions of the foot were performed in all patients using DBSPF (Table 1). In 2 (10%) of 20 cases, immediate reconstruction had been done after tumor resection (Fig. 6). In 11 (55%), coverage was done within 72 hours after a proper debridement of the devitalized necrotic tissue. The rest of the cases (35%) were operated on within 12 months after the initial injury due to the development of complications such as wound infection and dehiscence over the repaired Achilles tendon, development of osteomyelitis of the calcaneus after conservative management of a comminuted fracture of this bone requiring debridement, and excision of the overlying skin.

Flap dimensions ranged from 7×6 to 22×11 cm. All flaps survived completely. One flap developed distal venous congestion that resolved spontaneously with foot elevation without development of subsequent necrosis.

Pivot point of the flap was kept as low as 2–6 cm from the lateral malleolus in 8 cases with more distal reach to the heel and anterior ankle without any recorded complication.

DISCUSSION

Reconstruction of the distal third of leg, heel, ankle, and foot defects remains a challenge. Free microvascular flaps are ideal for such defects, but in cases with small-to-moderate–size defects or when microsurgery is not available, several surgeons have tried to innovate different flaps. Distally based sural artery neurocutaneous flap is one of the useful options described by Masquelet et al.[9] in 1992 and Hasegawa et al.[10] in 1994. However, venous congestion and fixed flap dimension were the main limitations that attracted many surgeons to add further into it. Ayyappan and Chadha[11] used super-flap to shift the proximal limit near popliteal crease,[11] and

Table 1. Summary of Patients' Data and Results

Patients	Age (y)	Sex	Etiology	Defect Size (cm)	Location of the Defect	Doppler Perforator above Lateral Malleolus (cm)	Pivot Point above Lateral Malleolus (cm)	Flap Size (cm)	Time Procedure	Comorbidities	Complications
1	25	M	Ulcer	12×6	Heel	6, 4, 2	4	15×8	1 mo	Smoking	None
2	65	M	SCC midfoot	10×9	Foot sole	6, 4, 2, 1	2	22×11	Immediately	Smoking	Wound infection
3	6	M	Avulsion injury	11×7	Achilles tendon	6, 4, 3	4	13×9	72 h	None	Spontaneous distal congestion relief
4	8	M	Crush injury	13×8	Achilles tendon	6, 4, 3	4	15×10	1 mo	None	None
5	7	M	Traffic accident	9×7	Medial malleolus	6, 4, 3	4	14×9	72 h	None	None
6	8	M	Traffic accident	8×6	Anterior ankle joint	6, 4, 3	3	11×8	72 h	None	None
7	26	M	Traffic accident	13×8	Achilles tendon	6, 4, 3	3	15×10	72 h	Smoking	None
8	68	M	Traffic accident	8×7	Anterior ankle joint	6, 4, 3	4	11×9	72 h	Diabetes, smoking	None
9	48	F	Ulcer	8×7	Achilles tendon	6, 4, 3	4	11×9	1 mo	Diabetes	None
10	9	M	Avulsion injury	9×6	Achilles tendon	6, 4, 3	4	11×9	72 h	Smoking	None
11	25	F	Sinus	5×4	Heel	6, 4, 2	3	7×6	2 mo	None	None
12	60	M	Chronic ulcer	9×5	Heel	6, 4, 2	2	11×7	45 d	Diabetes, smoking	Wound infection
13	27	M	Chronic ulcer	11×5	Heel	6, 4, 2	2	13×7	1 mo	None	None
14	60	M	SCC hindfoot	11×8	Heel	6, 4, 2	2	22×11	Immediately	Smoking	None
15	7	M	Avulsion injury	10×5	Achilles tendon	6, 4, 3	4	12×7	72 h	None	Wound infection
16	9	M	Crush injury	11×6	Achilles tendon	6, 4, 3	4	13×7	1 mo	None	None
17	10	M	Traffic accident	10×6	Medial malleolus	6, 4, 3	4	12×8	72 h	None	None
18	9	M	Avulsion injury	8×6	Achilles tendon	6, 4, 3	4	10×8	72 h	Smoking	None
19	26	M	Achilles tendon	11×6	Achilles tendon	6, 4, 3	3	13×8	72 h	Smoking	None
20	58	M	Anterior ankle joint	8×7	Anterior ankle joint	6, 4, 3	4	11×9	72 h	Smoking	None

SCC, squamous cell carcinoma.

others such as Tan et al.[12] proposed single-stage supercharging of flap; Wong and Tan[13] used intermittent short saphenous phlebotomy, and Fujiwara et al.[14] did temporary venous supercharging. A few surgeons included the gastrocnemius muscle beneath the fascia as described by Al Quattan,[15] Le Fourn et al.,[16] and Mueller et al.[17] in 2001 to further rectify it. The use of a distally based peroneus brevis muscle is another entity that was described by Eren et al.[18] and further improved by Schmidt and Giessler.[19]

Our flap is unique in nature as it uses peroneus brevis muscle along with sural skin island pedicle. This is the first flap to be described in the literature that implies using peroneus brevis muscle along with sural neurocutaneous flap to augment the blood supply of the proposed flap. In our clinical study, a ramification of the median sural artery within peroneus brevis muscle and a communication with the perforators of peroneal artery was observed. Initially, the perforators were found to be septocutaneous, which became musculocutaneous as we approached lateral malleolus. To preserve the ramifications, we included peroneus brevis muscle along with fasciocutaneous sural nerve territory (Fig. 4), which not only added muscle bulk but also augmented blood supply.

Grandjean et al.[5] have successfully used distally based sural artery flap in children with an age range of 1.5–17 years, with an average of 8.8 years. In our study, the age groups vary from 6 to 68 years.

Bajantri et al.[20] do not recommend using peroneus brevis muscle alone when the defect size exceeds 4 cm. Some authors have used sural flap maximum to hind foot.[14] In our series, the maximum flap dimension exceeds 13×8 cm, and we have used it for midfoot defects because of its versatile design (Fig. 5).

Flap pivot point is one of the criteria that is always controversial. Despite some authors who have consented to stay at 6 cm from lateral malleolus to include constant peroneal perforators,[21] in our series we premarked the perforators with hand-held Doppler and have gone up to 4, 3, and even 2 cm from lateral malleolus safely, which increases the distal reach of the flap.

Comorbid conditions like smoking and diabetes have been a relative contraindication of using propeller flap and free flaps,[22] but we have used this flap successfully in 2 such patients. In most of the cases, flap outcomes were good when flap cover was done within 72 hours of trauma after a proper debridement as suggested by Godina[23] and Byrd et al.[24] However, we have used this flap without any evidence of eventful episodes in case of nonhealing ulcers as supported by Fodor et al.[25] to use musculoneurocutaneous flap in distal tibial osteomyelitis.

We found venous congestion in only 1 of 20 patients, which was less, in comparison to other studies,[26] and 3 patients developed wound infection, which was settled with treatment of antibiotics and dressing. The success of our technique is probably due to careful dissection around distal vasculature, preserving neurovascular plexus and its ramification into muscle, always preserving short saphenous veins and their oscillating branches in the adipofascial pedicle, and postoperative limb elevation and splintage. None of our flaps required secondary procedures because of a better blood supply and the presence of muscle. The skin provided better aesthetic outcomes as compared with only muscle flaps that required skin grafting over the muscle (Fig. 6).[27]

Fig. 5. Preoperative margins outlined of a chronic ulcer in the midplantar region.

The main advantage of using peroneus muscle with sural neurocutaneous skin and fascia was a better blood supply (flap reaching to distal foot defects, thus lowering the pivot point), with no functional deformity of using peroneus muscle.

However, more anatomical studies are required to demonstrate communications of median sural artery and its ramification into peroneus muscle. So this flap points toward a new tool in plastic surgery for reconstruction of ankle, distal leg, and foot defects.

Fig. 6. Flap good healing and graft donor site at the 15th day.

CONCLUSIONS

DBSPF is reliable and easy to perform. This can be a new flap in the armamentarium of the reconstructive surgery for the distal third of leg, ankle, foot, and heel defects. As the flap entails preservation of the ramifications of median sural artery in the peroneus brevis muscle and also the ramifications of peroneal artery, there were fewer incidences of flap necrosis and venous congestion. Also, this flap was found to be reliable even when based on more distal perforators of the peroneal artery, thus increasing the distal reach of this flap. It is a good option for small-to-moderate–size defects with good aesthetic and functional outcome and with minimum donor-site morbidity.

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REFERENCES

1. Masquelet AC, Gilbert A. An atlas of flaps of the musculoskeletal system. Transfers from the lower limb. *Essex*. 2010; 186–187.
2. Ramesha Kunchekoppal T, Ghuge A, Shankarappa M, et al. Comparison between peroneus brevis flap and reverse sural artery for coverage of lower one-third leg defects. *ISRN Plast Surg*. 2014(2014):969420. DOI: 10.1155/2014/969420.
3. Wan L, James M, Yong CP, et al. Distally based sural artery adipofascial flap based on a single sural nerve branch: anatomy and clinical applications. *Arch Plast Surg*. 2014;41:709–715.
4. Ensat F, Hladaik M, Larcher L, et al. The distally based peroneus brevis muscle flap—clinical series and review of the literature. *Microsurgery*. 2014;34:203–208.
5. Grandjean A, Romana C, Fitoussi F. Distally based sural flap for ankle and foot coverage in children. *Orthop Traumatol Surg Res*. 2016;102:111–116.
6. Chen SL, Chen TM, Wang HJ. The distally based sural facsiomusculocutenous flap for foot reconstruction. *J Plast Reconstr Aesthet Surg*. 2006;59:846–855.
7. Vaienti L, Di Matteo A, Gazzola R, et al. Distally based sural fasciomusculocutenous flap for treatment of wounds of distal third of the leg and ankle with exposed internal hardware. *J Orthop Traumatol*. 2012;13:35–39.
8. Chang SM, Zhang K, Li HF, et al. Distally based sural fasciomyocutaneous flap: anatomic study and modified technique for complicated wounds of lower third leg and weight bearing heel. *Microsurgery*. 2009;29:205–213.
9. Masquelet AC, Romana MC, Wolf G. Skin island flaps supplied by the vascular axis of the sensitive superficial nerves: anatomic study and clinical experience in the leg. *Plast Reconstr Surg*. 1992;89:1115–1121.
10. Hasegawa M, Torii S, Katoh H, et al. The distally based superficial sural artery flap. *Plast Reconstr Surg*. 1994;93:1012–1020.
11. Ayyappan T, Chadha A. Super sural neurofasciocutaneous flaps in acute traumatic heel reconstructions. *Plast Reconstr Surg*. 2002;109:2307–2313.
12. Tan O, Atik B, Bekerecioglu M. Supercharged reverse-flow sural flap: a new modification increasing the reliability of the flap. *Microsurgery*. 2005;25:36–43.
13. Wong CH, Tan BK. Intermittent short saphenous vein phlebotomy: an effective technique of relieving venous congestion in the distally based sural artery flap. *Ann Plast Surg*. 2007;58: 303–307.
14. Fujiwara M, Nagata T, Matushishta Y, et al. Delayed distally based sural flap with temporary venous supercharging. *Microsurgery*. 2013;33:534–538.
15. Al Quattan MM. A modified technique for harvesting the reverse sural artery flap from the upper part of the leg: inclusion of a gastrocnemius muscle cuff around the sural pedicle. *Ann Plast Surg*. 2001;47:269–278.
16. Le Fourn B, Caye N, Pannier M. Distally based sural fasciomuscular flap: anatomic study and application for filling leg or foot defects. *Plast Reconstr Surg*. 2001;107:67–72.
17. Mueller JE, Ilchmann T, Lowatscheff T. The musculocutaneous sural artery flap for soft-tissue coverage after calcaneal fracture. *Arch Orthop Trauma Surg*. 2001;121:350–352.
18. Eren S, Ghofrani A, Reifenrath M. The distally pedicled peroneus brevis muscle flap: a new flap for the lower leg. *Plast Reconstr Surg*. 2001;107:1443–1448.
19. Schmidt AB, Giessler GA. The muscular and the new osteomuscular composite peroneus brevis flap: experiences from 109 cases. *Plast Reconstr Surg*. 2010;126:924–932.
20. Bajantri B, Bharthi R, Ramkumar S, et al. Experience with peroneus brevis muscle flaps for reconstruction of distal leg and ankle defects. *Indian J Plast Surg*. 2013;46(6):48–54.

21. Follmar KE, Baccarani A, Baumeister SP, et al. Distally based sural flap. *Plast Reconstr Surg.* 2007;119:138e–147e.
22. Eser C, Kesiktas E, Gencel E, et al. An alternative method to free flap for distal leg and foot defects due to electrical burn injury: distally based cross-leg sural flap. *Ulus Travma Cerrahi derg.* 2016;22(1):46–51.
23. Godina M. Early microsurgical reconstruction of complex trauma of extremities. *Clin Plast Surg.* 1986;13:619–620.
24. Byrd HS, Spicer TE, Cierney G 3rd. Management of open tibial fractures. *Plast Reconstr Surg.* 1985;76:719–730.
25. Fodor L, Horesh Z, Lerner A, et al. The distally based sural musculoneurocutaneous flap for treatment of distal tibial osteomyelitis. *Plast Reconstr Surg.* 2007;119:2127–2136.
26. Kneser U, Brockmann S, Leffler M, et al. Comparison between distally based peroneus brevis and sural flaps for reconstruction of foot, ankle and distal lower leg: an analysis of donor-site morbidity and clinical outcome. *J Plast Reconstr Aesthet Surg.* 2011;64:656–662.
27. Pers M, Medgyesi S. Pedicle muscle flaps and their applications in the surgery of repair. *Br J Plast Surg.* 1973;26:313–321.