CLINICAL RESEARCH ARTICLE

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# The use of propeller perforator flaps for diabetic limb salvage: a retrospective review of 25 cases

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***Background***: Peripheral vascular disease and/or diabetic neuropathy represent one of the main etiologies for the development of lower leg and/or diabetic foot ulcerations, and especially after acute trauma or chronic mechanical stress. The reconstruction of such wounds is challenging due to the paucity of soft tissue resources in this region. Various procedures including orthobiologics, skin grafting (SG) with or without negative pressure wound therapy and local random flaps have been used with varying degrees of success to cover diabetic lower leg or foot ulcerations. Other methods include: local or regional muscle and fasciocutaneous flaps, free muscle and fasciocutaneous, or perforator flaps, which also have varying degrees of success.

***Patients and methods***: This article reviews 25 propeller perforator flaps (PPF) which were performed in 24 diabetic patients with acute and chronic wounds involving the foot and/or lower leg. These patients were admitted beween 2008 and 2011. Fifteen PPF were based on perforators from the peroneal artery, nine from the posterior tibial artery, and one from the anterior tibial artery.

***Results***: A primary healing rate (96%) was obtained in 18 (72%) cases. Revisional surgery and SG for skin necrosis was performed in six (24%) cases with one complete loss of the flap (4%) which led to a lower extremity amputation.

***Conclusions***: The purpose of this article is to review the use of PPF as an effective method for soft tissue coverage of the diabetic lower extremity and/or foot. In well-controlled diabetic patients that present with at least one permeable artery in the affected lower leg, the use of PPF may provide an alternative option for soft tissue reconstruction of acute and chronic diabetic wounds.

Keywords: *diabetes mellitus*; *ulcers*; *lower leg*; *foot*; *propeller perforator flaps*

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The lifetime risk of developing an ulcer among patients with diabetes mellitus is about 12–25% (1, 2). The lower leg and foot ulcers are an important risk factor for amputation (3) with some authors reporting that 23–25% from the diabetic population undergo immediate amputation (4, 5) or even more than 55% in other statistics (6). Moreover, after major amputation in diabetics, the 5 year mortality rate can be up to 78% (7), and the risk of a contralateral limb amputation can be up to 50% (8). Despite the paucity of some authors in complex diabetic limb salvage techniques (9, 10), it has been proven that diabetic ulcers can be successfully treated through various reconstructive methods such as skin grafting (SG) with or without negative pressure wound therapy (NPWT), dermal substitutes (11–14) or by utilizing a large variety of pedicled and free flaps (12, 15–25).

It is well-known that the blood supply of the distal lower leg and foot is ensured by the contribution of the peroneal artery (PA), anterior tibial artery (ATA), and posterior tibial artery (PTA) through their musculocutaneous (MC) and septocutaneous (SC) perforators (25–27) (Fig. 1). This vascular supply occupies three vascular territories organized as a series of longitudinal rows within the intermuscular septa of the lower leg (25–27). The most distally located perforators and especially those emerging from the PA approximately 5 cm above the lateral malleolus (26, 28) and from the PTA approximately 5 cm above the medial malleolus (28) represent a very good vascular source for perforator flaps enabling



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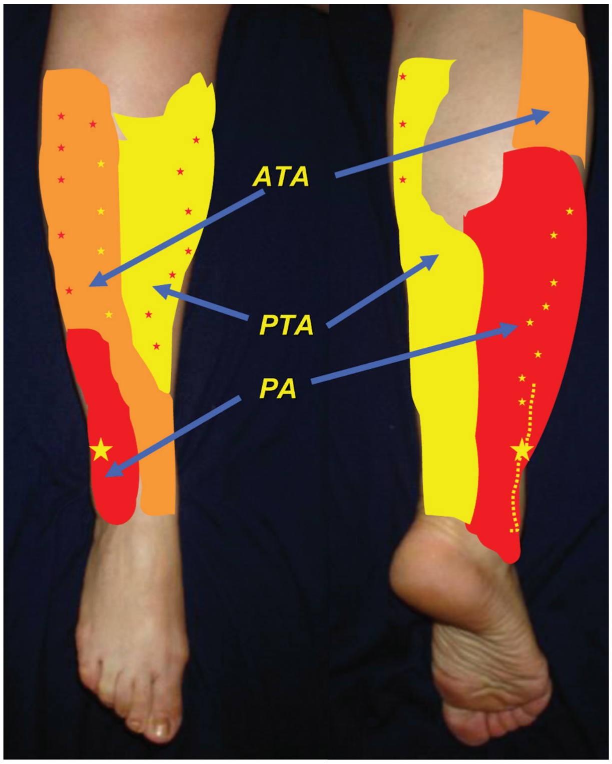


*Fig. 1.* This figure demonstrates the vascular territories of the main arteries in the lower leg. The stars represent the main distribution of perforators in each territory. ATA – anterior tibial artery; PTA – posterior tibial artery; PA – peroneal artery.

coverage of the foot and distal lower leg. The aim of this study was to retrospectively review the use of propeller perforator flaps (PPF) for soft tissue coverage of the diabetic lower extremity and foot in an overall period of 4 years.

## Patients and methods

A retrospective review between 2008 and 2011 for diabetic patients who underwent PPF reconstruction for soft tissue coverage of the lower leg and foot was performed in our institution (Table 1). There were a total of 24 patients (25 ulcerations) with 12 in the foot and 13 in the lower leg.

A handheld Doppler ultrasound and/or color Doppler examination was performed in all diabetic patients while an arteriography was performed in 15 patients. All patients had an acceptable vascular supply at the time of admission, even if in 13 patients only one artery was patent (PA in 11 cases and PTA in two cases). In seven patients, a previous revascularization was performed.

After hospital admission, sterile soft tissue cultures were obtained, broad-spectrum antibiotics were administered, and the ulcerations were locally treated for 3–7 days until the disappearance of inflammatory signs. In all cases, the surgical debridement and soft tissue defect coverage were performed at the initial operation.

The arterial choice based on which the PPF was performed was made according to the pre-operative Doppler and/or arteriographic examinations with the final decision made during operation and according to the intra-operative findings.

The results of the study were analyzed according to the type and dimensions of the flaps, post-operative complications, number of operations, wound healing rates, time to heal, number of limb salvage, and patient survival rates. The patient follow-up was between 6 and 51 months, with an average of 33.6 months.

## Results

There were 24 diabetic patients with ulcerations in 25 limbs (Table 1). The male-to-female ratio was 19:5 with the mean age of 69.1 years old (range, 39–81 years). The ulcer location was found in the distal lower leg in 13 cases and in the foot in 12 cases, from which six were in the weight bearing area of the foot (Case Nos. 3, 6, 9, 12, 17, and 23). All of the patients except three (Case Nos. 3, 7, and 10) had associated risk factors of atherosclerosis with ischemic cardiomyopathy, hypertension, and peripheral arterial disease. In seven patients, a previous lower extremity revascularization was performed.

The 25 PPF performed consisted of 15 PA-PPF, nine PTA-PPF, and one ATA-PPF. The flaps were based on SC perforators in 19 cases, and on MC perforators in six cases. The dimensions of the flaps were averaged from $8 \times 3$ to $31 \times 12$ cm. The flap donor sites were directly closed in five cases while in the remaining cases the donor sites were closed in combination of suturing and SG.

In 18 cases the flaps healed without complications, with an overall primary healing success rate of 72%. Comparing this rate for each type of flap, we obtained a primary healing in one case from one ATA-PPF, in 10 cases from 15 PA-PPF, and in seven cases from nine PTA-PPF. There were six complications (24%) (five PA-PPF and one PTA-PPF) consisting in partial superficial necrosis (SN) of no more than 50% of their entire flap surface, which were revised by surgical debridement and SG. One full necrosis of the flap (PTA-PPF) led to a lower extremity amputation (4%). The overall success rate including the revisional surgeries was at 96% with a mean time to heal of 46.2 days (range, 21–91 days). The average follow-up was 33.6 months (6–51 months) with post-operative follow-ups of all patients being able to ambulate without any assistant devices and one patient using a prosthesis.

## Discussion

It has been shown that the attempt for diabetic limb salvage should be encouraged since this is the single way to decrease the amputation rate and to increase the


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*Table 1.* Epidemiology, surgical treatment and outcomes

| No. | Etiology/wound site | Sex | Age | PPF | Size (cm) | Complication/ treatment | Healing time, days | Limb salvage |
|---|---|---|---|---|---|---|---|---|
| 1 | PAOD/plantar aspect distal foot | M | 57 | PA/SC | 20 × 5 | – | 45 | + |
| 2 | PAOD/Achilles region | M | 60 | PA/SC | 8 × 3 | – | 31 | + |
| 3 | PAOD/plantar foot | F | 45 | PA/SC | 18 × 7 | Partial SN/SG | 63 | + |
| 4 | PAOD. Posttr. non-healing wound/dorsal ankle* | M | 56 | PA/SC | 28 × 10 (prox); 28 × 3 (distal) | – | 49 | + |
| 5 | Venous insufficiency/distal lower leg | F | 68 | ATA/SC | 12 × 4 | – | 28 | + |
| 6 | PAOD. Posttr. non-healing wound/calcaneum | M | 65 | PA/SC | 20 × 8 | – | 33 | + |
| 7 | PAOD. Venous insufficiency/distal lower leg* | M | 57 | PTA/MC | 15 × 7 | – | 35 | + |
| 8 | PAOD/Achilles region | M | 62 | PA/SC | 17 × 4 | Partial SN/SG | 91 | + |
| 9 | PAOD/calcaneum* | M | 58 | PTA/SC | 18 × 5 | Partial SN/SG | 78 | + |
| 10 | Frostbite/bilateral TMA stumps | M | 66 | PTA/SC; PA/SC | 28 × 10; 26 × 7 | – | 25; 37 | + |
| 11 | PAOD. Posttr. non-healing wound/distal lower leg | M | 74 | PA/MC | 17 × 7 | Partial SN/SG | 67 | + |
| 12 | PAOD/calcaneum | M | 70 | PTA/MC | 22 × 5 | – | 40 | + |
| 13 | PAOD. Posttr. non-healing wound/lateral malleolus | M | 72 | PTA/MC | 15 × 7 | Complete necrosis | 63 | Amputation |
| 14 | Venous insufficiency/distal lower leg | M | 66 | PA/MC | 12 × 6 | – | 27 | + |
| 15 | PAOD. Posttr. non-healing wound/distal lower leg* | M | 50 | PA/MC | 15/4 | – | 35 | + |
| 16 | Venous insufficiency/distal lower leg | M | 81 | PTA/SC | 10 × 5 | – | 47 | + |
| 17 | PAOD/plantar foot* | M | 39 | PA/SC | 31 × 12 (prox) 31 × 3 (distal) | – | 36 | + |
| 18 | PAOD. Non-healing wound after amputation for gangrene/TMA stump | M | 61 | PTA/SC | 21 × 9 | – | 21 | + |
| 19 | PAOD. Venous insufficiency. Posttr. non-healing wound/distal lower leg | M | 47 | PA/SC | 17 × 12 | Partial SN/SG | 82 | + |
| 20 | PAOD/Achilles region | F | 65 | PTA/SC | 17 × 6 | – | 23 | + |
| 21 | PAOD. Posttr. non-healing wound/lateral malleolus* | F | 52 | PA/SC | 13 × 5 | – | 39 | + |
| 22 | Venous insufficiency/distal lower leg | M | 65 | PTA/SC | 8 × 5 | – | 43 | + |
| 23 | PAOD/calcaneum* | M | 65 | PA/SC | 20 × 5 | Partial SN/SG | 88 | + |
| 24 | PAOD. Non-healing wound/lateral foot | F | 58 | PA/SC | 14 × 5 | – | 29 | + |

*Patients with previous revascularization; PA – peroneal artery; ATA – anterior tibial artery; PTA – posterior tibial artery; SC – septocutaneous perforator; MC – musculocutaneous perforator; SN – superficial necrosis; SG – skin grafting; PAOD – peripheral arterial obstructive disease; M – male; F – female; Posttr. – Post-traumatic; TMA – transmetatarsal amputation; Prox – proximal.

long-term survival in the diabetic population (23, 24). Once the necessity for reconstructive surgery in salvaging the diabetic foot has been better understood, a growing number of surgical options were introduced. The SG of such ulcerations is not generally a viable option since the grafts may not incorporate completely on the majority of diabetic wounds. In addition there is a high risk of ulcer recurrence after SG. Adjunctive therapeutic techniques such as negative pressure wound dressings (29), skin substitutes (11, 13, 30, 31), growth factors (32), hyperbaric oxygen (33–35), and extracorporeal shockwave therapy (35–37) have all been utilized to increase the chance of skin graft incorporation. However, the risk of ulcer recurrence still remains high. Yeh et al. (14) reported on SG as a salvage procedure for reconstruction of the diabetic foot with a wound healing rate of 74% at 1 month, 86.3% at 2 months, but with non-healing in five cases at 3 months, requiring stump revision in three cases.

Due to the limited amount of soft tissue resources for flap reconstruction in the lower leg and foot, it is generally considered that local or regional flaps could provide a viable option. However, there are several drawbacks including: the involvement of the neighboring tissue (12), the frequency of donor site SG including portions of the original defect (38, 39), and the high complication rate of some neurocutaneous flaps (40).

The use of local muscle flaps could be a good alternative for covering defects of small dimensions in the midfoot, hindfoot, or ankle (23), but larger defects require a free microsurgical flap. Both cutaneous and muscle free flaps can be used successfully in the diabetic foot. Oishi et al. (41) considered it more advantageous to use cutaneous free flaps due to the lower incidence of recipient site problems while Ducic and Attinger (23) considered muscle free flaps for better long-term durability and less functional complications. This surgical approach with muscle coverage is ideal for the plantar foot defects (23, 42) even if some surgeons have indicated that fasciocutaneous flaps can also be successfully used (20, 41, 43).

In recent years, the free perforator flaps started to be extensively used in diabetic foot ulcers (20, 44–46). Despite the high success rate of free microsurgical flaps (even in diabetic patients; (20, 44–48)), there are several

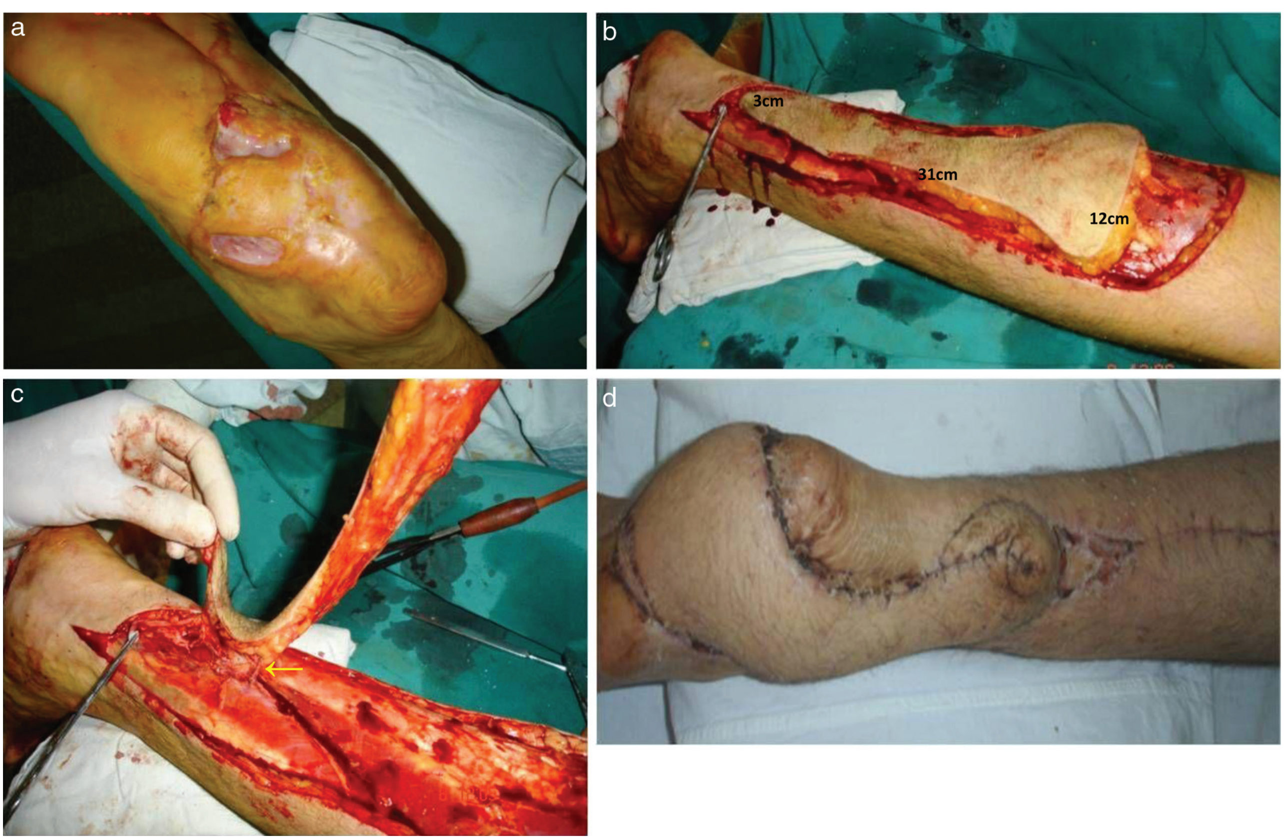


*Fig. 2.* Pre-operative clinical view (a) of a non-healing plantar foot ulcerations for the patient in Case No. 17. Intra-operative view showing the harvesting of the perforator flap based on a distal perforator from the peroneal artery (PA) with dimensions of 31 cm in length and 12 cm of width in the proximal aspect and 3 cm of width in the distal aspect (b). Intra-operative view of the harvested flap with the arrow indicating the perforator emerging from the PA about 9 cm above the lateral malleolus (c). Clinical picture at 1-month post-operative follow-up (d).


*Fig. 3.* Pre-operative clinical view (a) of a non-healing dorsal ankle wound for the patient in Case No. 4. Intra-operative view showing the harvesting of the perforator plus flap based on a distal perforator from the peroneal artery with dimensions of 28 cm in length and 10 cm of width in the proximal aspect and 3 cm of width in the distal aspect (b). Intra-operative view of the harvested flap in continuity at its base with the donor site and forceps indicating the sural nerve (c). Post-operative clinical views at 2 weeks (d) and 1 year follow-up (e, f).

drawbacks in using them including: the necessity of a well-controlled diabetic patient, longer anesthesia and operative time, distant donor site, necessity of good recipient vessels, and microsurgical skills. Moreover, when a free flap has failed, further limb salvage reconstructive techniques may be limited to the diabetic patient.

Recent advances in the vascular anatomy of the lower leg (25–28, 49–56) have stimulated the interest in performing pedicled perforator flaps in the lower extremity.

Schaverien and Saint-Cyr (27) found in their study that, from distal to proximal, the location of perforators able to support a viable flap were within the 4–9 cm area emerging from the ATA and PTA with one to two perforators from the PA; in the 13–18 cm region, perforators were emerging from the PA and PTA; and in the 21–26 cm region, perforators were emerging from the ATA and PTA (Fig. 1). In diabetic patients with vascular compromise there is still usually a patent major vascular axis, most commonly being the PA (57) with viable perforators to support a perforator flap.

In our case series, the distal perforators (Fig. 2) as described by Schaverien and Saint-Cyr (27) emerging from the distal 4 to 9 cm region were mainly utilized. In this region, two very constant and reliable perforators, one at 5 cm proximal to the medial malleolus emerging from the PTA (28) and the other 5 cm proximal to the lateral malleolus emerging from the PA were founded in our patient population (25, 26, 28).

In some cases, when the condition of the local tissues surrounding the defect were poor or when a perforator in the distal 4–9 cm region was not found, the flaps were based upon perforators emerging from the medial third of the tibia (located in the 13–18 cm region) (25). The vascularization of the lower limb was acceptable for all patients upon hospital admission, even if in 13 cases the vascular supply was provided by only one major arterial trunk (PA in 11 cases and PTA in two cases).

Considering the major complications for these types of flaps with post-operative venous congestion that can lead in some circumstances to partial or even complete flap necrosis, a design flap improvement was executed.


*Fig. 4.* Pre-operative clinical view (a) of a non-healing distal lower extremity wound with tibia necrosis for the patient in Case No. 19. Intra-operative view showing the harvested peroneal based perforator flap with dimensions of 17 cm in length and 12 cm of width (b). Post-operative view showing the superficial necrosis of the distal third of the flap after venous congestion (c). The flap was revised and surgically debrided (d) with adequate granulation tissue 7 days after the revisional surgery (e) when skin grafting was performed. Post-operative clinical outcome at 6 months follow-up (f).

This surgical artifice, called the perforator plus flap, was the preservation of a cutaneous bridge at the base of the flap, connecting the flap with the donor area (42, 58, 59). This surgical procedure was successfully utilized but unlike the original technique, the cutaneous bridge in our series was very narrow (25) (Fig. 3).

In the 24% complication rate reported in our diabetic patient population, the superficial partial skin necrosis (Fig. 4) was due to venous congestion which was revised by surgical debridement and SG that was performed within 7 days after the initial operation. In addition, one PTA-PPF had completely failed in a 72-year old male with a lateral malleolus defect that eventually led to an amputation. No mortality rates were recorded in the 4-year follow-up.

In conclusion, based on our results (primary healing in 72% of cases with an overall 96% healing rate), careful consideration on utilizing the PPF in reconstruction of the diabetic lower extremity should be based on the patient's overall medical status, wound size, status and location, arterial blood supply, and other surgical treatment options.

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