# Propeller perforator flaps for coverage of soft tissue defects in the middle and distal lower extremities

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ORIGINAL ARTICLE

# Propeller perforator flaps for coverage of soft tissue defects in the middle and distal lower extremities

## *Lambeaux perforants en hélice dans la couverture des pertes de substance au membre inférieur*

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**KEYWORDS**
Perforator flap;
Propeller flap;
Soft tissue defect;
Lower limb

**Summary**
*Introduction.* — The middle and distal leg coverage is demanding procedure for reconstructive surgeon until evolution of local perforator flaps which becomes as valuable options in lower limb reconstruction. The goal of our study was to assess the results, reliability, safety, and possible complications of the local propeller perforator flaps in lower extremity reconstruction.
*Patients and methods.* — We demonstrate a case series of 11 patients in whom we cover small-to-medium soft-tissue defects of the middle and distal leg by application of local propeller perforator flaps.
*Results.* — The site of soft tissue defects were in the distal third in 9 cases (81.8%) and 2 cases (18.1%) in the middle third. Flap dimensions ranged from 48 to 192 $cm^2$, with an average size of 88.9 $cm^2$. The flap rotation was 180 degrees in (63.6%) of cases. The flaps were based on a single perforator of the posterior tibial artery in 8 (72.7%) cases and peroneal artery perforator in 3 (27.2%) cases. Complications were present in 18% of the perforator flaps which were based on peroneal artery perforator, one partial necrosis and one flap with a superficial epidermolysis. The donor area is covered by split thickness skin graft in 63.6% of our cases and primary closure of in 36.3% of cases.

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*Conclusion.* — The perforator propeller flaps are safe, relatively simple procedure and consider as an ideal option in reconstructing small-medium defects of the middle and distal third of the leg which provide similar skin texture with low donor site morbidity.


**MOTS CLÉS**
Lambeaux perforants en hélice ;
Perte de substance ;
Membre inférieur

**Résumé**
*Introduction.* — La couverture médiane et distale des jambes est une procédure exigeante pour le chirurgien reconstructeur jusqu'à l'évolution des lambeaux perforants locaux, qui deviennent une option valable pour la reconstruction des membres inférieurs. Le but de notre étude était d'évaluer les résultats, la fiabilité, la sécurité et les complications possibles des lambeaux perforants en l'hélice lors de la reconstruction des membres inférieurs.
*Patients et méthodes.* — Nous présentons une série de cas de 11 patients chez lesquels nous couvrons des défects de tissus mous de taille petite à moyenne du tiers moyen et distal de la jambe par la réalisation de lambeaux locaux perforants en hélice.
*Résultats.* — Les pertes de substance des tissus mous se situaient au tiers distal dans 9 cas (81,8 %) et 2 cas (18,1 %) au tiers moyen. Les dimensions des lambeaux allaient de 48 à 192 $cm^2$, avec une taille moyenne de 88,9 $cm^2$. La rotation des lambeaux était de 180 degrés (63,6 %) des cas. Les lambeaux étaient basés sur une seule perforante de l'artère tibiale postérieure dans 8 cas (72,7 %) et sur une perforante de l'artère péronière dans 3 cas (27,2 %). Des complications étaient présentes dans 18 % des lambeaux perforants, lesquels étaient basés sur une perforante de l'artère péronière, une nécrose partielle et un lambeau avec une épidermolyse superficiale. La zone donneuse est couverte par une greffe de peau expansée 63,6 % des cas et une fermeture primaire dans 36,3 % des cas.
*Conclusion.* — Les lambeaux perforants en hélice constituent une procédure relativement simple et sûre. Ils constituent une option idéale pour la reconstruction des défauts de taille petite à moyenne du tiers moyen et distal de la jambe qui fournissent une texture de peau similaire avec une faible morbidité au site donneur.


## Introduction

Simple or complex lower extremities soft tissue defects especially in the distal leg, remains to be a demanding procedure for reconstructive surgeons. Local fasciocutaneous flaps have both restricted availability and mobility in the distal leg [1,2]. Although muscle flaps used mainly in the proximal leg coverage [3], it has a limited role in reconstruction of the distal leg besides associated functional deficit sequel. Free microvascular transfer have been the first option to provide adequate coverage of cutaneous defects especially in the lower leg [4], however it is time consuming procedure, necessitates microsurgical experiences and associated facility.

During the most recent years, with advancement in the anatomical knowledge on cutaneous, subcutaneous, and intramuscular perforating vessels emerging from main vascular axis of the lower limbs [5—7], the strategy for management of lower-limb soft tissue defects has significantly changed with the establishment of local perforator flaps. Koshima and Soeda in 1989 were for the first time utilized the declaration of ''perforator flap'' for a paraumbilical skin flap based on a muscular perforator [8]. Hyakusoku et al., in 1991 was first reported the term propeller flap as a fasciocutaneous flap rotated 90 degrees to cover post-burn contracture defects in cubital and axillary areas [9]. Afterward, Teo [10] could provide a higher amount of rotation by entirely skeletonize the perforator vessel to be based on a single pedicle.

Advancement in the knowledge perforator vessel anatomy of the leg and its relation to the surrounding muscles has strongly influenced the application of perforator flaps technique in lower extremity reconstruction. Moreover, these anatomical studies have described a diversity in the dissection and design of perforator flaps [11,12] which result in its succeeding definition and classification [13].

With the introduction of both perforator flap and propeller design concept, the reconstruction of lower limb extremity had remarkably advanced. The perforator flap provides a safe flap elevation with reliable, constant vascularity and associated low donor site morbidity. In addition, propeller flap design adds a distinctive advantage of broad arc of rotation to increase the flap reach [14].

The purpose of this study was to evaluate clinical outcomes of local perforator flaps as a surgical alternative option in reconstruction of small-medium size soft-tissue defects in the middle-distal third of the leg.

## Patients and methods

A retrospective study was conducted between September 2016 and October 2018 in patients presented to our plastic surgery departments with post traumatic soft-tissue defects of the mid-distal third of the leg who underwent reconstruction with perforator-based propeller flaps technique. Patient's charts were reviewed and including: patient demographics, cause of the defect, location of the defect, source

of perforator vessel, dimensions of the flap, degree of rotation of the flap, donor site closure and post-operative complications. The procedures followed were in accordance with the ethical committee of Faculty of Medicine and the Helsinki Declaration. Informed consent was obtained from all patients in this study.

## Surgical technique

All procedures were operated under spinal anesthesia and all patients were operated in the supine position. Application of pneumatic tourniquet without prior exsanguination was done for easily dissection. Loupe magnification (3.5 X) was used during flap harvesting procedures for easy dissection. After selection of the main vascular axis, the site of perforators was detected by color Doppler imaging. The standard longitudinal design of a propeller flap was positioned proximal to the defect. The typical flap design consisted of two paddles, a major paddle length matched the defect's length from the pivot point proximally. The other was a minor paddle, which involved the tissue between the pivot point and the superior margin of the defect. Following flap marking and to detect all the possible perforators, we carried out an exploratory skin incision on one edge of the flap. Afterward, the ultimate flap shape was re-designed and then the incision was completed. The selected perforator was skeletonized from the surrounding fibrous septa for a minimum 2 cm, this decreases the risk of torsion of the pedicle after rotation of the flap [15]. The flap then was rotated around the pivot point, inset and secured into the defect. The donor area is partially resurfaced with the minor distal flap paddle, and the rest is resurfaced by split thickness skin graft or closed primarily. Postoperatively, the limb was lifted up for at least 48 hours to minimize the hazard of venous congestion, and any compression on the flap should be avoided.

## Results

In the study period, eleven male patients were operated for the reconstruction of defects localized at the middle and distal third of the leg (Table 1). The average patients' age was 32.8 years (range, 18 to 52 years). All soft tissue defects caused from trauma. The site of soft tissue defects were in the distal third in 9 cases (81.8%) and 2 cases (18.1%) present in the middle third. Out of eleven patients, three cases had external fixation device, three cases showed associated exposed plate over lower third of the leg and five patients had exposed tibial bone. The flap size ranged from 12 × 4 cm (48 $cm^2$) to 24 × 8 cm (192 $cm^2$), with an average flap dimension of 88.9 $cm^2$. The flap was rotated 180 degrees in seven (63.6%) cases, 160 degrees in 1 (9%) case, 140 degrees in 1 (9%) case and 90 degrees in 2 (18.1%) cases. The perforator vessel source was the posterior tibial artery in 8 (72.7%) cases (Figs. 1–3) and the peroneal artery in 3 (27.2%) cases (Fig. 4).

**Table 1** Patient demography, clinical data and results of all cases reconstructed with perforator-based propeller flap.

| | Age/sex | Etiology | Site of defect | Flap dimensions (cm) | Rotation degrees | Source artery and number of perforators | Donor Site closure | Complications |
|---|---|---|---|---|---|---|---|---|
| **1** | 35/M | Trauma (Ex. Fix) | Medial malleolus | 12 × 6 cm (72 $cm^2$) | 180° | Posterior tibial artery (one) | Skin graft | No |
| **2** | 29/M | Trauma (Ex. Fix) | Middle third | 11 × 6 cm (66$cm^2$) | 90° | Posterior tibial artery (one) | Skin graft | No |
| **3** | 50/M | Trauma (exposed plate) | Lower third | 24 × 8 cm (192 $cm^2$) | 180° | Peroneal artery (One) | Skin graft | Partial necrosis |
| **4** | 30/M | Trauma (exposed plate) | Distal third | 12 × 4 cm (48 $cm^2$) | 180° | Posterior tibial artery (One) | Skin graft | No |
| **5** | 18/M | Unsteady scar | Lateral calcaneal region | 25 × 5 cm (125 $cm^2$) | 180° | Peroneal artery (one) | Simple closure | Superfacial epidermolysis |
| **6** | 35/M | Trauma | Lower third | 15 × 5 cm (75 $cm^2$) | 180° | Peroneal artery (one) | Simple closure | No |
| **7** | 31/M | Trauma | Lower third | 16 × 5 cm (80 $cm^2$) | 180° | Posterior tibial artery (one) | Simple closure | No |
| **8** | 28/M | Trauma (Ex. Fix) | Middle third | 15 × 6 cm (90 $cm^2$) | 90° | Posterior tibial artery (one) | Skin graft | No |
| **9** | 48/M | Trauma (exposed plate) | Lower third | 18 × 6 cm (108 $cm^2$) | 160° | posterior tibial artery (one) | Skin graft | No |
| **10** | 25/M | MCA | Achilles tendon | 14 × 5 cm (70 $cm^2$) | 180° | Posterior tibial artery (one) | Skin graft | No |
| **11** | 32/M | Trauma | Lower third | 13 × 4 cm (52 $cm^2$) | 140° | Posterior tibial artery (one) | Simple closure | No |


**Figure 1** (Patient no. 4). A. Male patient, 30 years old, presented by skin defect at medial aspect of distal third with plate exposed, with design of perforator flap based on perforators from the posterior tibial artery. B. After elevation of the flap. C. The flap rotated 180° to the defect. D. After insetting of the flap. E. Immediate post-operative view, note donor site closure by split thickness skin graft. F. Three month post-operative.

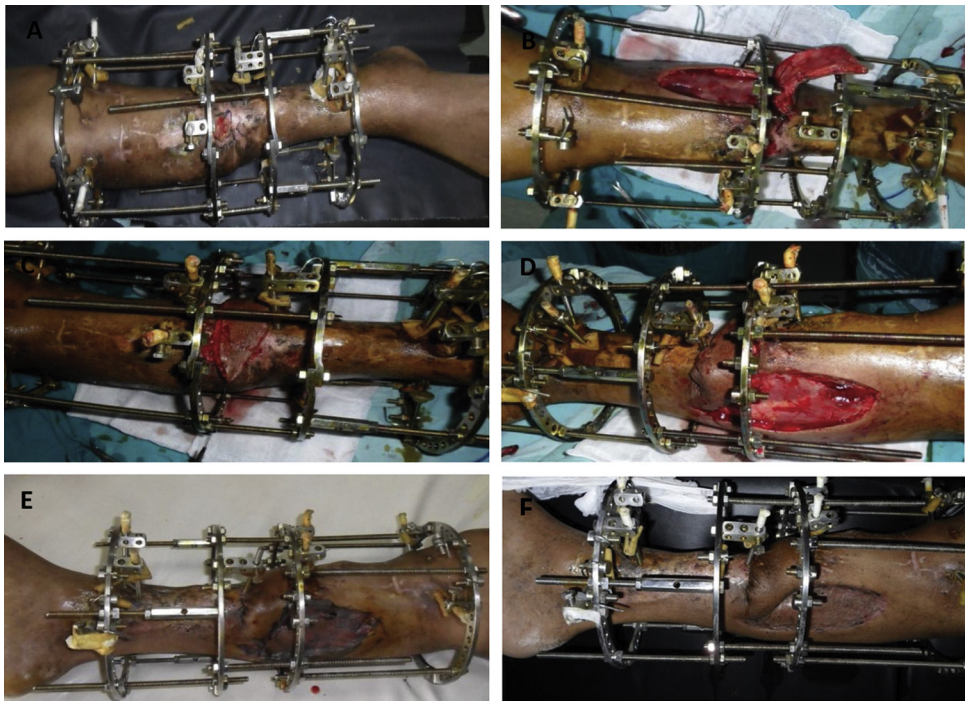


**Figure 2** (Patient no. 2). A. Male patient, 29 years old, with defect at middle third of right leg with plate exposed and external fixator was applied. B. After elevation of the flap based on perforators from the posterior tibial artery. C, D. The flap rotated 90° and insetted to the defect. E. Post-operative view after one week, note donor site closure by split thickness skin graft. F. Post-operative view after 4 months.


**Figure 3** (Patient no. 11). A. Male patient, 32 years old, presented by small skin defect at medial aspect of distal third with exposed tibia. B. Perforator flap based on posterior tibial artery perforator was elevated, rotated 140° and insetted to the defect. C. Post-operative view after two months.


**Figure 4** (Patient no. 5). A. Male patient, 18 years old, had old trauma, presented by unsteady scar at left lateral calcaneal region and design of perforator flap based on perforators from the peroneal artery was done. B. Immediate post-operative view after elevation of the flap, rotated 180° and insetting of the flap to the defect and donor site closed primary. C. Post-operative view after nine months.

Complications were present in 18% of the flaps which were based in the peroneal artery perforator. These included one partial necrosis (9%) which needed further surgical intervention and one flap with a superfacial epidermolysis (9%) which healed with conservative wound management without any further intervention. The donor area is covered by split thickness skin graft in 63.6% of the cases, while direct primary closure was done in 36.3% of cases. Patients were followed up for a period from 6 to 12 months (mean = 9 months).

## Discussion

Soft tissue defects of the lower extremities especially the distal leg continues to present a difficult reconstructive challenge to the plastic surgeon. The ideal soft tissue recon-

struction of the leg should be versatile, relatively simple to accomplish, provides similar skin texture to the missing ones, with minimal donor site morbidity.

Local options for coverage of lower leg defects are deficient. Random pattern fasciocutaneous flaps have high rate of failure due to unreliable vascularity besides its high donor site morbidity and the sequential bulky dog ear which is unappealing [16]. Muscle flap has a restricted role with the disadvantage of sacrifice of muscle function. Cross leg flap is easy flap solution but it has high donor site morbidity with prolonged immobilization of both lower extremities and two stage procedures [17]. Although free microsurgical flaps have been the first choice for reconstructive procedures in the lower leg [4], however with significant improvement in the knowledge of vascular anatomy of the lower limbs, there are paradigm shift in flap preference with development of recent variety of local propeller perforator flaps [18]. The perforator-based flaps can provide adequate coverage for small and medium sized cutaneous defects [19].

At our institution, we have been using propeller based perforator flap in eleven patients to cover post traumatic small-moderate size soft tissue defect with exposed bone or prostheses in the middle and distal third of the leg. Flap dimensions were ranged from (48 $cm^2$ to 192 $cm^2$) with average of 88.9 $cm^2$. Although the average size of perforator flaps in our study is larger than proposed by Gir et al. [20] of 67.1 $cm^2$, and Shin et al. of 63.8 cm [21], we could elevate most of our flaps (82%) based on one perforator without complication or vascular compromise with good healing potential. Moreover, Koshima et al. [5] could use perforator flap size of up to 19 $\times$ 13 cm based on single perforator from posterior tibial artery, while Rad et al. [22] reported a flap size of 22 $\times$ 8 cm which is based on single peroneal artery perforator. In our study, although we could use propeller posterior tibial artery perforator flaps measuring up to 18 $\times$ 6 cm without any complication, On the other hand, we could elevate peroneal artery perforator flap measuring up to 24 $\times$ 8 cm, but these cases showed vascular compromise complications in form of partial necrosis and superficial epidermolysis.

In this study we are capable to rotate the perforator flaps up to 180 degrees in seven (82%) cases, 160 degrees in two (18.1%) of the cases and 90 degrees in another two (18.1%) cases, which reveals its versatility to cover middle and distal third of the leg defects, comparable to reviewed in alternative series [19,23]. To avoid torsion of small perforating vessel during rotation of the flap, the perforator vessel dissection should be carried out carefully under loupe magnification (3.5X) for a short path through the muscle substance or inside the inter-muscular septa. Moreover division of all the fascial adhesions around the perforator is a necessary step to avoid compromising the blood flow during flap rotation especially the venous drainage.

We found 2 complications (18%) in our study, one case with partial necrosis (9%), and a superficial epidermolysis (9%) in one case. Two recent systematic review articles investigated the incidence of complications of the perforator flaps which were used for lower-extremity reconstruction. These studies which performed by Gir et al. [20] and Nelson et al. [24] analyzed 186 and 310 perforator flaps respectively and show comparable result in terms of total flap survival. However, partial flap necrosis was 11% in both reviews which is even higher that reported in our clinical series. Moreover, our study is practically comparable to a more recent meta-analysis investigation which was done by Bekara et al. [25] about perforator flaps in lower limb defects with overall complications rate of 25.2%, and partial necrosis in 10.2% of cases.

Although our result is comparable to that reported in the other literatures, the complications which occurred in our flaps are based mainly on peroneal artery perforator which also posses the largest flap dimension in our clinical series (125 cm and 192 cm).

The safe dimensional limit of the perforator flap is very difficult to predict how much is the skin size that could be nourished by one perforator [26]. In addition, perforators originating from the posterior tibial vessel, although small in number, their diameter are larger and more constant than those from the peroneal vessel, so larger flaps with more reliable vascularity can be raised on the medial side of the leg compared to the lateral aspect [7,12,27]. In our series, we could not conclude that the flap dimension did influence the survival rate of the transferred tissue as reported in previous literature [26], however, we recommend using perforator flap only to permit coverage of small-medium sized soft tissue defects in lower leg to avoid vascular compromising complications and trying not to overcome the dimensional limit allowed by one perforator. For these reasons, we mainly try to use posterior tibial artery as a source of perforators in eight cases, however, we used peroneal artery perforators only in three cases.

Although the donor area is partially covered with the distal part of the propeller flap, due to restricted tissue mobility in the distal leg, the rest is covered by split thickness skin graft. We recommended application of partial thickness skin graft as we did in 63.6% of our cases to avoid excessive tension on propeller flap during closure of the donor site defect, however we could close the donor site primarily in 36.3% of the cases.

Although we did not compare between the results of perforator and free flaps in our study, however, in a recent meta-analysis study [28] there is proof that overall failure and complications rate were 19.0% for free flaps versus 21.4% for propeller flaps which is comparable to our complication rate (18%). Meanwhile free flaps remain the first option for reconstruction of wide and complex soft tissue defects of the lower extremities [29,30], however propeller perforator flaps may represent a more suitable alternatives to cover small-to-medium size soft tissue defects over lower leg.

The perforator flaps advantages involves, preservation of the major vascular axes and underlying muscle with limited functional deficit of the lower extremity, allowing coverage like with like tissue without the need for a microsurgical anastomosis. Moreover, these flaps provide a consistent, predictable vascular supply and associated long pedicle to permit enough transposition with minimal donor site morbidity. On the other hand, its disadvantages include a carful perforator dissection to separate it from the surrounding tissue to avoid damage of the perforating vessel.

## Conclusions

Based on the outcomes presented in our study, we regard that perforator propeller flaps are safe, relatively simple

procedure and consider as an ideal option in reconstructing small-medium defects of the middle and distal third of the leg which provide similar skin texture with low donor site morbidity.

## Disclosure of interest

The authors declare that they have no competing interest.

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