Article published online: 2023-03-16

Use of Propeller Flaps for the Reconstruction of Defects around the Ankle

Fernando Benedetti, MD[1,2] Paola Kafury, MD[3] Fabiola Reyes-Arceo, MD[1] Carmelo Lizardo, MD[1] Federico Reina, MD[1] Mauricio Zuluaga, MD[1,2]

[1] Limb Lengthening and Reconstruction Unit, Clínica Imbanaco Grupo Quirón salud, Cali, Colombia
[2] Faculty of Health Sciences, Pontificia Universidad Javeriana Cali, Colombia
[3] Department of Plastic and Reconstructive Surgery, Clínica Imbanaco Grupo Quirón Salud, Cali, Colombia

Address for correspondence Mauricio Zuluaga, MD, Carrera 38A #5A-100 office 803 Tower A, Cali – 760042, Colombia (e-mail: info@mauriciozuluaga.com).

J Reconstr Microsurg Open 2023;8:e38–e44.

Abstract

Background This article describes the clinical results of the use of propeller flaps during reconstruction of coverage defects around the ankle.

Methods A retrospective study of all patients with bone and soft tissue defects around the ankle reconstruction using propeller flap between January 2021 and December 2022 was conducted. Flap survival rate and complications were the outcomes variables.

Results A total of 14 reconstructions in 13 patients (mean age: 45.8 ± 16.7 years) using propeller flaps were performed in the study period. The medial malleolus was the most affected area ($n = 5$) and the defect size ranged from 12 to 33.7 cm^2. The posterior tibial artery was used as a perforator in 11 flaps. Complications were identified in five flaps, four developed venous congestion and one case, reactivation of infection. Only one propeller flap presented complete failure associated with necrosis. Good soft tissue coverage was achieved in 13 of 14 flaps.

Conclusion Propeller flaps proved to be a valid management option during reconstruction of bone and soft tissue defects around the ankle, offering adequate coverage in most cases. Adequate patient selection is important to decrease the risk of complications.

Keywords
- propeller flap
- complications
- necrosis
- ankle

The reconstruction of complex coverage defects around the ankle with bone, joint, or tendon exposure is a challenge for the orthopedist. For the treatment of these lesions, the use of free or local flaps is usually required with the main objective of saving and preserving the limb, favoring functional and aesthetic results.[1,2] The introduction of perforator-based local flaps has represented a breakthrough in the field of reconstructive surgery because they preserve the vascular supply to the tissue.[3] In the last decade, the use of perforator-based propeller flaps has become popular, offering minimal donor site morbidity with a reported survival of at least 80%.[4–6] Additionally, although propeller flaps may have a higher complication rate compared to free flaps (21.5 vs. 14.0%), they may be a better treatment option because complications tend to evolve satisfactorily with a lower overall failure rate (3.7 vs. 6.0%) and a reduced cost of care equivalent to one-third of the cost associated with the use of free flaps.[7]

received
June 22, 2022
accepted after revision
October 31, 2022

DOI https://doi.org/10.1055/s-0043-1762894.
ISSN 2377-0813.

Thieme Medical Publishers, Inc., 333 Seventh Avenue, 18th Floor, New York, NY 10001, USA

Propeller flaps are characterized by a design that allows axial rotation of the flap up to 180 degrees and have been recommended mainly for the reconstruction of small to medium-sized defects in the thigh, knee, and medial leg. However, their use is less frequent in defects located in the ankle region. Therefore, other coverage options have been suggested, such as free flaps or the distal-based neurovascular sural fasciocutaneous flap.[3,4] This study aimed to describe the clinical results of the use of propeller flaps during the reconstruction of coverage defects around the ankle.

Methods

A retrospective review of a consecutive series of patients in whom propeller flaps were used during reconstruction of bone and soft tissue defects located around the ankle was performed. All cases were treated by the two senior authors (F. Benedetti and M. Zuluaga) in a limb lengthening and reconstruction unit between January 2020 and December 2021. No cases were excluded, and all were identified through the institutional clinical registry. This study was approved by the institutional review board (Approval Code: CEI-652) and conducted under the guidelines of the Declaration of Helsinki.

Age, sex, defect size, flap location, and associated bone lesions were gathered from institutional clinical records. The outcome variable was the occurrence of postoperative complications and flap survival. Donor site complications were also reviewed. All data were analyzed using a descriptive approach with Stata 17 software (Stata Corp, College Station, TX).

Indications and Surgical Technique

Propeller flap reconstruction was considered in small-to-medium coverage defects of tendons, bones, blood vessels, or osteosynthesis material. During the preoperative plan, a comprehensive assessment was performed to identify comorbidities or nutritional aspects that could affect the flap's healing process. All patients underwent a vascular study by angiotac or angiography to perform a functional evaluation of the main perforators of the distal third of lower limb (e.g., posterior tibial artery, peroneal artery, and anterior tibial artery). Before starting the surgical procedure, localization of the perforating artery was performed with portable Doppler or color Doppler ultrasound. Subsequently, a provisional flap design was made with the selected perforator and the pivot point. Then, the distance from the perforator to the distal edge of the defect was measured, and this measurement was used to approximate the proximal length along the longitudinal axis of the vessel, adding 1 to 2 cm. This last measurement corresponded to the maximum size of the upper limit of the flap. The width of the flap was determined based on the width of the covering defect by adding 0.5 cm. Care was always taken to leave 2 cm from the perforator to the edge of the flap. In all cases, a tourniquet was used on the thigh performing gravity exsanguination to maintain a vascular filling that allowed better visualization of the perforators. In addition, magnification with 3.5× loupes was used (►**Fig. 1**).

The procedure began with the anterior approach of the subfascial flap to locate the perforating artery, which was released up to the vessel to allow rotation of the pedicle without affecting circulation. Once the pedicle was identified and released, the tourniquet was deflated and the subfascial flap elevation was fulfilled by completing the proximal and posterior approach. Then, we waited 5 to 15 minutes after release to evaluate the perfusion of the flap and continue with its rotation.

The closure was made by planes with Vicryl or polydioxanone 2 and 3/0 suture, closing the skin with antitension flap stitches or stapler. When primary closure of the donor area was not achieved, it was covered with partial thickness skin grafts taken with electric dermatome and managed with the

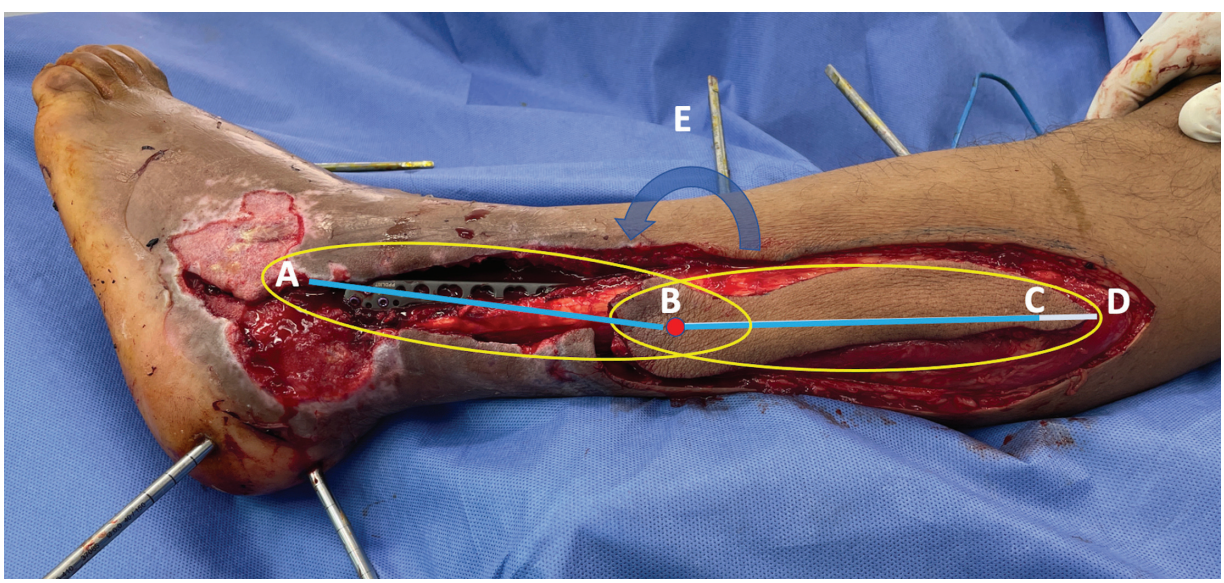

Fig. 1 Planning of the propeller flap for coverage of a left lateral fibula defect. (**A**) Most distal point to the coverage defect. (**B**) Location of the perforating artery. (**C**) Verification that the distance from point B to C is equal to the distance between A and B. (**D**) Addition of 2 cm from point C to D to reach the flap. (**E**) Propeller flap rotation with pivot point from the perforator.

Fig. 2 Case with coverage defect in the internal and external malleolar region after fibular osteosynthesis. (**A**) Wound dehiscence, infection, and skin necrosis. (**B**) Dehiscence of surgical wound in medial region on medial malleolus and coverage defect in plantar medial region.

VAC (vacuum-assisted closure) system. During the first 48 postoperative hours, the limb was kept elevated to reduce the risk of edema and venous congestion. The patient was discharged between the second and third postoperative days. In some cases, the use of a tripod-type external fixator was indicated to avoid pressure on the vascular pedicle and the flap.

►**Figs. 2** to **5** describe the clinical case of a patient with coverage defect in the internal and external malleolar region associated with infection of the operative site after implantation of osteosynthesis material to treat a trimalleolar luxofracture. This case was managed with Masquelet's induced membrane technique and propeller flap. Satisfactory results were obtained at the end of follow-up.

Results

Between 2020 and 2021, 13 patients (8 men, 5 women, mean age: 46.5 ± 19.2 years) reconstructed with propeller flaps for coverage defects around the ankle were identified, with a median follow-up of 12 months (interquartile range [IQR]: 3–16 months). The most common etiology was infectious ($n = 7$) and seven cases had an associated bone lesion (►**Table 1**). In total, 14 propeller flaps were performed and the most frequent area requiring coverage was the medial malleolus ($n = 5$). The defect area ranged from 12 to 33.7 cm^2 with a median of 16.0 cm^2 (IQR: 12.0–33.7 cm^2). Of the 14 flaps, the posterior tibial artery was used as perforator in 11 and the peroneal artery in the remaining 3.

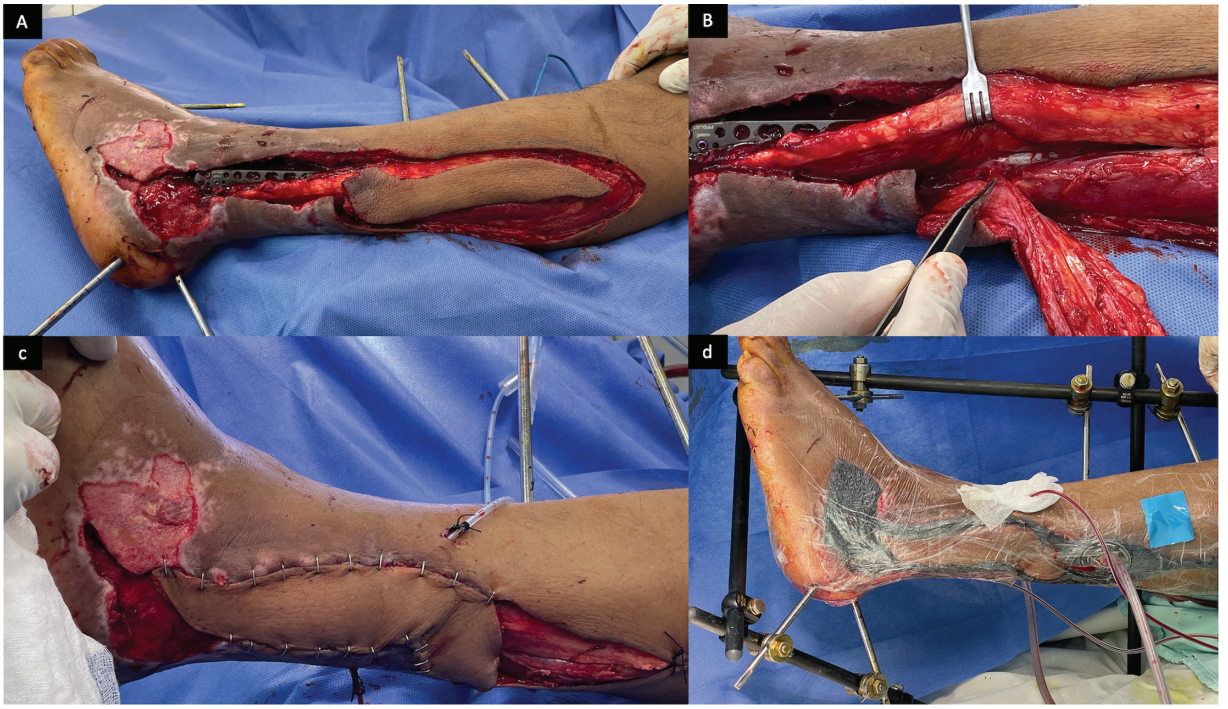

Fig. 3 (**A**) Flap dehiscence after reconstruction of fibula defect with Masquelet's induced membrane technique. (**B**) Peroneal artery dissection (perforator). (**C**) Propeller flap rotation to cover the defect. (**D**) Stabilization with external fixator in tripod to avoid hematoma formation and flap coverage with wound VAC (vacuum-assisted closure) system.

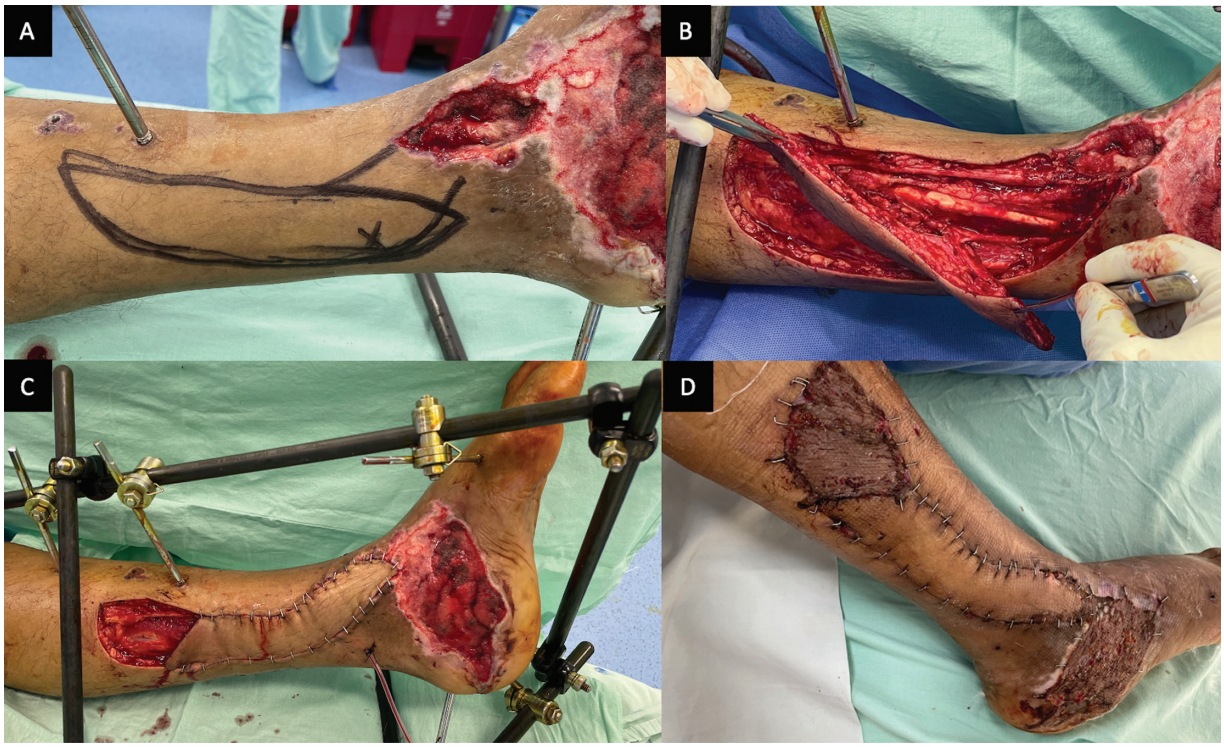

Fig. 4 (**A**) Planning of the propeller flap and identification of the perforating artery with color Doppler. (**B**) Dissection of the posterior tibial artery (perforator). (**C**) Propeller flap rotation to cover the defect over the medial malleolus. (**D**) Follow-up 5 days after partial thickness skin graft coverage of the defect in the medial region of the foot and donor area.

Fig. 5 Photograph showing the healing process of the flap and the final aesthetic results.

Table 1 Defect characteristics and clinical outcomes of patients reconstructed with propeller flap

Case	Age/Sex	Etiology	Defect site	Bone lesion	Dimension of the defect (in cm)	Perforator	Complications
1	46/M	Infection	Medial malleolus	Yes	15 × 5	Posterior tibial artery	No
2	47/M	Infection	Medial and lateral malleolus	Yes	Medial: 4 × 4 Lateral 3 × 10	Posterior tibial artery Peroneal artery	No
3	36/F	Infection	Antero medial tibial pylon	Yes	3 × 15	Posterior tibial artery	Venous congestion
4	61/F	Trauma	Medial malleolus	No	3 × 4	Posterior tibial artery	No
5	56/M	Trauma	Medial tibial pylon	Yes	2 × 8	Posterior tibial artery	No
6	31/F	Infection	Medial malleolus	No	4 × 6	Peroneal artery	Infection
7	79/M	Other	Achilles	No	4 × 3	Posterior tibial artery	Venous congestion/ Complete graft loss
8	49/M	Trauma	Tibialis distal anterior medial and lateral	Yes	5 × 15	Posterior tibial artery	Venous congestion
9	22/M	Trauma	Achilles	No	4 × 5	Posterior tibial artery	No
10	25/F	Trauma	Medial malleolus	No	4 × 3	Posterior tibial artery	No
11	21/M	Infection	Achilles	No	5 × 3	Posterior tibial artery	No
12	55/M	Infection	Lateral malleolus	Yes	5 × 3	Peroneal artery	No
13	77/F	Infection	Medial malleolus	Yes	4 × 3	Posterior tibial artery	Venous congestion

Abbreviations: F, female; M, male.

A total of five flaps developed some type of complication, four had venous congestion and one flap had an infection. No complications were reported at the donor site. Of the 14 reconstructions performed with propeller flaps, only one involved complete loss due to necrosis in a 79-year-old patient with diabetes mellitus and arterial insufficiency, who died secondary to acute myocardial infarction 2 months after the procedure. In consequence, good soft tissue coverage was achieved in 13 of the 14 flaps (►**Table 1**).

Discussion

Reconstructive surgery of defects located around the ankle aims to save the limb, preserving functionality as much as possible due to the important role it plays during standing. Local flaps with propeller design are an alternative to free flaps with advantages that allow (1) preserving vascularization, (2) reducing donor site morbidity, and (3) improving the aesthetic appearance due to the similarity between the tissues of the recipient and donor sites.[8] In addition, propeller flaps do not require microvascular anastomosis so they can be performed by surgeons without training in this surgical technique. However, this type of flaps can be demanding due to the microvascular dissection with a magnification of 2.5× to 3.5 × .

The main finding of this study revealed that the use of propeller flaps allows for achieving adequate coverage in bone and soft tissue defects located around the ankle, with a flap survival of 92.8%. In the literature, the survival of propeller flaps has varied between 88.9 and 100% in coverage defects around the ankle (►**Table 2**) and in general for the lower limbs a percentage of at least 80% has been estimated.[9,10] This has allowed suggesting that they should be considered as a first alternative for the reconstruction of coverage defects in lower limbs in small and medium-sized defects in patients with adequate vascular function.[11]

In this study, we found a high percentage of complications (five flaps, 35.7%) compared to other reported series (►**Table 2**). Among the four cases that developed venous congestion, only one presented complete flap failure. Venous congestion is the most frequent complication and requires early management to decrease the risk of necrosis and complete flap loss.[9,12] During our clinical practice, this complication is managed with removal of stitches from the flap to avoid tension and a revision surgery is performed to evaluate the presence of hematomas. The above protocol has allowed us to obtain a favorable evolution in most of our patients, preventing complete flap failure. Another aspect to highlight is that complications can be prevented through the implementation of a comprehensive preoperative plan that allows adequate patient selection and identification of risk factors based on patient characteristics (e.g., age or diabetes) and tissue characteristics (e.g., vascular analysis).

In this cohort, different propeller flap orientations were used according to the needs of each case, selecting the shortest possible arc of axial rotation of the flap. Song et al[13] demonstrated that flap perfusion is a factor that depends on the direction of rotation, resulting in variations

Table 2 Studies describing clinical outcomes with the use of propeller flaps in the reconstruction of defects around the ankle

Year	Author	Number of flaps	Perforator artery	Complications	Flap survival
2012	Karki and Narayan[7]	20	Posterior tibial artery Peroneal artery	Total: 4 (20%) Venous congestion: 2 Partial necrosis: 1 Wound dehiscence: 1	20 (100%)
2017	Shen et al[18]	36	Posterior tibial artery	Total 12 (33.3%) Venous congestion: 9 Hematocele: 1 Infection: 1 Necrosis: 1	34 (94.4%)
2019	Dhar et al[11]	9	Posterior tibial artery	Total: 2 (22.2%) Venous congestion: 1 Epidermolysis: 1	8 (88.9%)
2021	Yildirim et al[6]	20	Posterior tibial artery Peroneal artery	Total: 4 (20%) Partial necrosis: 2 Epidermolysis: 2	20 (100%)
2021	Eldahshoury et al[19]	23	Posterior tibial artery Peroneal artery	Total: 4 (17.4%) Venous congestion: 2 Wound dehiscence: 2	22 (95.7%)
2022	Benedetti et al (Present study)	14	Posterior tibial artery Peroneal artery	Total: 5 (35.7%) Venous congestion: 4 Infection: 1	13 (92.8%)

in flow velocity and flow volume rate. Consequently, the use of duplex ultrasound may be a useful tool to choose the optimal orientation, which may result in fewer cases with total or partial flap loss.[13] In the particular case of interventions performed in the lower extremities, where the rate of venous congestion is higher ($\sim$ 11%),[14] color Doppler ultrasound assessment is a valuable tool that allows an accurate vascular assessment and an adequate design of the preoperative plan, leading to minor complications after the procedure.[15]

Due to the high percentage of complications associated with the use of propeller flaps, some authors have tried to identify factors associated with the risk of complication in order to modify or control these variables during the surgical procedure. Thus, Wang et al[9] reported that a shorter distance between the perforator and the defect location decreases complications by 19.4%, suggesting a maximum distance of 3.5 cm. Additionally, in the same study, it was reported that a rotation range between 150 and 180 degrees may be associated with an even higher risk of complications. This latter finding is similar to that reported by Shahabuddin and Khurram[5] who described a higher number of cases with necrosis among flaps with an arc of rotation of 150 to 180 degrees (2/20) compared to those rotated between 90 and less than 150 degrees (0/20). In addition, it has been suggested to consider the use of propeller flaps in extensive trauma, as well as in patients with a history of diabetes mellitus, peripheral obstructive disease, or with inadequate perforators.[7,9]

On the other hand, comparable results have been found in terms of overall complications and flap failure when comparing the clinical results of reconstructions performed with free and propeller flaps.[11,16] Bekara et al[17] in a meta-analysis analyzing 55 studies (free flaps: 36 studies and propeller flaps: 16 studies), reported that propeller flaps had a higher rate of partial necrosis compared to free flaps (2.7 vs. 6.9%, $p > 0.05$), but with a lower rate of wound dehiscence (2.4 vs. 0.3%, $p > 0.05$) and infection (4.4 vs. 1.2%, $p > 0.05$). The rate of complete tissue loss was similar between both types of flaps (3.9 vs. 2.8%, $p < 0.05$). Additionally, Innocenti et al[10] reported that propeller flaps were a more cost-effective option compared to free flaps, due to the shorter operative time and days of hospital stay required for optimal evolution.

The small sample size, the inclusion of patients in a single center, and the retrospective nature of this study represent its main limitations, which limit the generalizability of the results. Based on our experience, propeller flaps are considered an ideal option for the management of coverage defects, especially in hospitals with limited financial resources. Even so, they must be performed by trained personnel with experience in soft tissue management and microvascular dissection techniques to avoid complications and improve the prognosis of the flap.

Conclusion

Propeller flaps proved to be a valid management option during the reconstruction of bone and soft tissue defects around the ankle, offering adequate coverage in most cases. Adequate patient selection is important to decrease the risk of complications.

Conflict of Interest
None declared.

Acknowledgment
We thank Biopublest for statistical support.

References

1 Bhullar DS, Karuppiah SV, Aljawadi A, et al. Local flaps vs. free flaps for complex lower limb fractures: Effect of flap choice on patient-reported outcomes. J Orthop 2019; 17:91–96

2 Zeiderman MR, Pu LLQ. Contemporary approach to soft-tissue reconstruction of the lower extremity after trauma. Burns Trauma 2021;9:tkab024

3 AlMugaren FM, Pak CJ, Suh HP, Hong JP. Best local flaps for lower extremity reconstruction. Plast Reconstr Surg Glob Open 2020;8 (04):e2774

4 Tajsic N, Winkel R, Husum H. Distally based perforator flaps for reconstruction of post-traumatic defects of the lower leg and foot. A review of the anatomy and clinical outcomes. Injury 2014;45 (03):469–477

5 Shahabuddin SF, Khurram MF. A study of clinical applications of perforator-based propeller flaps in leg reconstructive surgery: a single-center experience of 40 cases. Int J Low Extrem Wounds 2020;19(01):70–77

6 Yildirim T, Unsal SS, Armangil M. Propeller flap: orthoplastic approach for coverage of distal leg and ankle defects. Foot Ankle Surg 2021;27(08):874–878

7 Karki D, Narayan RP. The versatility of perforator-based propeller flap for reconstruction of distal leg and ankle defects. Plast Surg Int 2012;2012:303247

8 Teo TC. Propeller flaps for reconstruction around the foot and ankle. J Reconstr Microsurg 2021;37(01):22–31

9 Wang P, Lin F, Ma Y, Wang J, Zhou M, Rui Y. Predictors of the surgical outcome of propeller perforator flap reconstruction, focusing on the effective safe distance between the perforator and the wound edge. BMC Musculoskelet Disord 2021;22(01): 643

10 Innocenti M, Dell'Acqua I, Famiglietti M, Vignini L, Menichini G, Ghezzi S. Free perforator flaps vs propeller flaps in lower limb reconstruction: a cost/effectiveness analysis on a series of 179 cases. Injury 2019;50(Suppl 5):S11–S16

11 Dhar LK, Talukder A, Kaiser A, Razia S, Jahan I, Islam MS. Posterior tibial artery perforator based propeller flap for lower leg and ankle defect coverage: a prospective observational study. Mymensingh Med J 2019;28(02):311–316

12 Bekara F, Herlin C, Mojallal A, et al. A systematic review and meta-analysis of perforator-pedicled propeller flaps in lower extremity defects: identification of risk factors for complications. Plast Reconstr Surg 2016;137(01):314–331

13 Song S, Jeong HH, Lee Y, et al. Direction of flap rotation in propeller flaps: does it really matter? J Reconstr Microsurg 2019;35(08):549–556

14 Ibrahim RM, Gunnarsson GL, Akram J, Sørensen JA, Thomsen JB. Color Doppler ultrasonography targeted reconstruction using pedicled perforator flaps-a systematic review and meta-analysis. Eur J Plast Surg 2018;41(05):495–504

15 Hong JP, Hur J, Kim HB, Park CJ, Suh HP. The use of color duplex ultrasound for local perforator flaps in the extremity. J Reconstr Microsurg 2022;38(03):233–237

16 D'Arpa S, Toia F, Pirrello R, Moschella F, Cordova A. Propeller flaps: a review of indications, technique, and results. BioMed Res Int 2014;2014:986829

17 Bekara F, Herlin C, Somda S, de Runz A, Grolleau JL, Chaput B. Free versus perforator-pedicled propeller flaps in lower extremity reconstruction: What is the safest coverage? A meta-analysis. Microsurgery 2018;38(01):109–119

18 Shen L, Liu Y, Zhang C, et al. Peroneal perforator pedicle propeller flap for lower leg soft tissue defect reconstruction: clinical applications and treatment of venous congestion. J Int Med Res 2017;45(03):1074–1089

19 Eldahshoury T, Cacciola R, El-Gazzar K. Safety and vascular impact of perforator propeller flaps during distal lower limb reconstruction. Plast Reconstr Surg Glob Open 2021;9(12):e3993