Research Square

Preprints are preliminary reports that have not undergone peer review.
They should not be considered conclusive, used to inform clinical practice,
or referenced by the media as validated information.

Pedicle Mini Flap Prevents Distally Based Flap Circulation Disturbance by Reducing Venous Congestion of the Flap: A Retrospective Comparative Study

Ke Xu
The Second Affiliated Hospital of Soochow University
Yongyang Sun
Zhangjiagang Hospital Affiliated to Soochow University
Bo Jiang
The Second Affiliated Hospital of Soochow University
Jiaju Zhao
The Second Affiliated Hospital of Soochow University
Yong Zhang
The Second Affiliated Hospital of Soochow University
Zhicheng Zuo
The Second Affiliated Hospital of Soochow University
Yi Nan
The Second Affiliated Hospital of Soochow University
Jupu Zhou
zhoujupu@126.com

The Second Affiliated Hospital of Soochow University

Research Article

Keywords: Distally based flap, Soft tissue defect, Mini flap, Microsurgery, Reconstruction

Posted Date: November 12th, 2026

DOI: https://doi.org/10.21203/rs.3.rs-11186534/v1

License: This work is licensed under a Creative Commons Attribution 4.0 International License.
Read Full License

Additional Declarations:

No competing interests reported.

Tables 1 to 3 are available in the Supplementary Files section.

Pedicle Mini Flap Prevents Distally Based Flap Circulation Disturbance by Reducing Venous Congestion of the Flap: A Retrospective Comparative Study

Ke Xu MS[1, †], Yongyang Sun MS[2, †], Bo Jiang MD[1], Jiaju Zhao MS[1], Yong Zhang MS[1], Zhicheng Zuo MS[1], Yi Nan MD[1], Jupu Zhou MS[1,*]

[1] Department of Hand and Foot Surgery, The Second Affiliated Hospital of Soochow University, Suzhou, 215004, China.Tel: +86-512-67784127.

[2] Department of Hand and Foot Surgery, Zhangjiagang Hospital Affiliated to Soochow University, Suzhou, 215600

† Ke Xu and Yongyang Sun contributed equally to this study.

Corresponding authors: Email address: zhoujupu@126.com (Jupu Zhou), Department of Hand and Foot Surgery, The Second Affiliated Hospital of Soochow University, Suzhou, 215004, China.

Conflict of Interest Statement

The authors declare no competing interests.

Abstract

Background: The treatment of soft tissue defects remains a significant clinical challenge, particularly in the lower extremity. Distally based flaps are commonly used to address these defects; however, blood circulation disturbances often compromise their effectiveness. This study explores the clinical benefits of the pedicle mini flap in preventing such circulation issues, offering a potential solution to enhance flap viability and improve patient outcomes.

Methods: A retrospective analysis was conducted on 78 patients who underwent distally based flaps repair for skin and soft tissue defects with exposed critical structures in the lower limbs at our institution between October 2014 and June 2023. Patients were divided into two groups: the traditional distally based flap group and the pedicle mini group, based on the presence of a pedicle mini flap design. Flaps survival and appearance were assessed during follow-up.

Results: In the distally based flap group, 1 patient experienced a postoperative arterial crisis, which improved after surgical exploration. 10 patients had venous crises, with six developing partial necrosis, which healed after secondary skin grafting. 2 patients experienced complete flap necrosis, which was resolved with subsequent surgery. The remaining 29 patients had satisfactory flap survival. In the pedicle mini flap group, 32 patients had

excellent flap circulation with complete survival. 6 patients developed venous crises, with 4 experiencing partial flap necrosis, but no arterial crises or complete flap necrosis occurred.

Conclusion: Adding a mini-flap at the pedicle of distally based flaps was associated with a trend toward lower venous congestion, though the difference was not statistically significant. This simple modification may help preserve pedicle vasculature and reduce external compression, representing a potential adjunctive technique.

Evidence level: IV

Keywords: Distally based flap; Soft tissue defect; Mini flap; Microsurgery; Reconstruction

Introduction

Flaps are commonly used in the treatment of soft tissue defects, but they still pose significant challenge[1]. Soft tissue defects are often caused by trauma, diabetic foot, or skin neoplasms, and in certain cases, flap reconstruction is required to achieve optimal clinical functional recovery[23]. Flap transplantation has become a routine and effective method for repairing large and complex soft tissue defects. However, in cases where the area of soft tissue loss is extensive, the unpredictable blood supply to the flap can lead to partial necrosis, especially in the distal part, making this a significant challenge in

surgical practice[4]. Distally based flap, characterized by their proximity to the recipient wound, ease of harvesting, and large rotation arc, have been widely used in clinical practice[5,6,7]. However, complications such as pedicle torsion, venous congestion, and even partial or complete flap necrosis are not uncommon post-operatively[8]. It is important to note that partial flap necrosis after distally based flap surgery is usually initiated not by arterial ischemia but by venous congestion[9]. Once venous congestion occurs, it may lead to extravasation of red blood cells, rupture of the vascular endothelium, microvascular collapse, arterial ischemia, and thrombosis within the microcirculation, ultimately resulting in flap failure[10,11]. Flap necrosis not only necessitates secondary surgeries but also causes significant patient suffering and financial burden[12,13]. To prevent pedicle compression and improve blood circulation in distally based flaps, we have designed a mini flap at the pedicle to address venous congestion and enhance the survival rate of the flap. This study aims to evaluate the impact of the presence or absence of pedicle mini flap on the survival rate of distally based flaps.

Materials and Methods

All patients provided written informed consent prior to participation in this study. The study was approved by the Institutional Review Board (IRB) of our institution. Ethics approval and consent to participate: This study was approved by the Ethics Committee. All participants provided written informed

consent. We retrospectively reviewed all patients with soft tissue injuries who were treated at our hospital between October 2014 and June 2023. A total of 128 patients were ultimately included in the study.

Inclusion criteria: (1) Age between 25 and 75 years; (2) Use of distally based flaps for wound reconstruction; (3) Follow-up duration of at least 12 months with complete clinical data.

Exclusion criteria: (1) Patients with multiple traumatic injuries who were not suitable for surgery; (2) Patients with concomitant peripheral vascular disease; (3) Patients with severe systemic diseases; (4) Patients whose wound could not be completely covered by a single flap.

Patients were divided into two groups based on whether a pedicle mini flap was designed: (1) Distally Based Flap Group and (2) Pedicle Mini Flap Group. All surgeries were performed by a single experienced surgeon. Demographic data, including sex, age, related medical history （including smoking，hypertension，and diabetic），etiology of injury, injury site, and operations before flap were recorded for all patients. The skin defect area and the flap area were measured as the product of the maximum width and maximum length (in centimeters). According to the calculated area, defects were classified into small (<36 cm^2), medium (≥36 to <100 cm^2), and large (≥100 cm^2). The flap was monitored for vascular compromise, specifically arterial ischemia and venous congestion. When venous congestion occurred, the final

flap outcome was categorized into survival after salvage (successful rescue by conservative intervention), partial necrosis (loss of a portion of the flap), or complete necrosis (total flap loss). In addition, the postoperative infection was documented as the proportion of all patients that developed clinical signs of infection requiring antibiotic treatment or surgical drainage.

Surgical technique

All surgeries were performed under either spinal anesthesia or general anesthesia. After thorough debridement, the first step was to repair the deep tissues, including fractures and tendons injury. Based on the arterial perforator status of the donor area, as assessed by Doppler ultrasound, and the size of the recipient wound, an appropriate distally based flap was designed for reconstruction.

For the Pedicle Mini Flap Group, the design of the pedicle mini flap was based on the location of the soft tissue defect, the type of flap chosen, and the direction of the blood supply to the arterial perforators in the donor area as assessed by preoperative Doppler ultrasound. A circular or spindle-shaped mini flap was designed at the pedicle, centered on the axis of the flap and the flap's pivot point. The mini flap was designed such that the proximal and distal portions each accounted for half of the total area, allowing for easy 180° rotation either in the retrograde or anterograde direction during surgery. The area of the pedicle mini flap should not be too large, with sizes in this group

ranging from 1.0 cm × 1.0 cm to 5.0 cm × 3.0 cm.

The incision line was designed according to the principles of flap points, lines, and surfaces. First, the side of the pedicle mini flap was incised. The perforating arteries in the donor area were carefully identified, and once the blood vessels were confirmed, the incision was extended to the other side of the pedicle mini flap and distally based flap until the entire flap was released. Dissection was carried out from the proximal to distal end of the flap to the rotation point. The pedicle, connecting the main flap and the mini flap, was gradually freed in the subcutaneous tissue, ensuring that the vascular fascial pedicle remained sufficiently wide during dissection. （Fig.1 &Fig.2）

In cases where a distally neuro-fasciocutaneous flap or fascia-pedicled reverse flow island flap was used, dissection started from the body of the flap to the rotation point, with a 2–5 cm wide fascial tissue pedicle preserved at the pedicle. The mini flap at the pedicle was then incised on both sides. After harvesting the flap, it was transferred to the recipient area through either a direct or tunnel approach. If conditions allowed, the nerve of the flap was anastomosed to the nerve of the recipient area. The superficial venous trunk of the pedicle was preserved. The donor site wound was either directly sutured or covered with a skin graft. (Fig.3)

The procedure for the Distally Based Flap Group was similar to that for the Pedicle Mini Flap Group, with the exception that no mini flap was designed

at the pedicle. The flap was directly transferred to the recipient area through either a direct or tunnel approach.

Postoperatively, both groups routinely had a drain placed, underwent light source warming, elevation of the affected limb, and prophylactic antibiotic administration. The flap was closely monitored for swelling, bruising, and exudation, and the viability of the flap's blood supply was carefully observed.

Statistical analysis

Data were analyzed using SPSS Statistics (version 26.0, IBM Corp., Armonk, NY, USA). Continuous variables were expressed as mean ± standard deviation (SD), and categorical variables as frequencies (percentages). The Shapiro–Wilk test was used to assess the normality of continuous data, and Levene's test was employed to evaluate homogeneity of variances; all continuous variables in this study satisfied the assumptions of normal distribution and homogeneity of variances (all $P > 0.05$). Accordingly, between-group comparisons for continuous variables were performed using the independent-samples T-test. Categorical variables were compared using the chi-square test. A two-sided $P < 0.05$ was considered statistically significant. No sample size calculation was performed prior to the study given its retrospective nature.

Results

Baseline characteristics

A total of 128 patients were initially enrolled. However, 50 patients were

excluded due to incomplete follow-up data (n = 32) or loss to follow-up (n = 18). Ultimately, 78 patients were included in the final analysis: 40 in the Distally Based Flap Group and 38 in the Pedicle Mini Flap Group.

The baseline characteristics of the two groups were well balanced. There were no significant differences between the two groups in age, gender distribution, related medical history（including smoking， hypertension，and diabetic），etiology, defect location, skin defect size, or number of operations before flap (Table 1). All continuous variables met the assumptions of normal distribution and homogeneity of variance prior to T-test analysis.

Surgical outcomes

In the Distally Based Flap Group, 29 of 40 patients (72.5%) achieved flap survival; however, 1 patient developed an arterial crisis that resolved after surgical exploration, and no flap loss occurred as a result. In the Pedicle Mini Flap Group, 32 patients (84.2%) had flap survival, and no arterial crisis occurred in this group. The difference in flap survival rate was not statistically significant ($P = 0.210$) (Table 2).

Venous congestion and necrosis

Venous congestion occurred in 10 patients (25%) in the Distally Based Flap Group and in 6 patients (15.7%) in the Pedicle Mini Flap Group; this difference did not reach statistical significance (Table 2). For the Distally Based Flap Group, 2 of 10 patients improved with conservative treatment

(bloodletting, limb elevation, and heparin ointment), achieving complete flap survival. Six patients developed partial necrosis, and 2 patients experienced complete flap necrosis, both of whom recovered after a second free flap surgery.For the Pedicle Mini Flap Group, 2 of 6 patients improved with conservative treatment. Four patients developed partial necrosis, and no complete necrosis occurred in this group.

Among patients who developed partial necrosis, the necrotic area was 29.33 ± 7.50 cm^2 in the Distally Based Flap Group and 24.25 ± 8.54 cm^2 in the Pedicle Mini Flap Group, with no significant difference between groups (P = 0.371). However, the proportion of necrotic area relative to total flap area was significantly smaller in the Pedicle Mini Flap Group (22.11 ± 2.74%) compared to the Distally Based Flap Group (31.32 ± 6.74%, P = 0.020) (Table 3).

Wound infection and other complications

Wound infection occurred in 3 patients (7.5%) in the Distally Based Flap Group and in 4 patients (10.5%) in the Pedicle Mini Flap Group (P = 0.640) (Table 2). All infections resolved after dressing changes and local debridement. Donor sites healed primarily in all patients without major complications.

Discussion

In this study, we compared the clinical outcomes of the Distally Based Flap group and the Distally Based Flap group combined with a Pedicle Mini-Flap.

Compared to the Distally Based Flap group, incorporating a mini-flap at the vascular pedicle reduced the risk of postoperative venous congestion. Furthermore, the pedicle mini-flap design increased pedicle width, which lowered the technical difficulty of flap elevation and reduced the risk of pedicle injury associated with excessive dissection. Postoperative flap survival was favorable, with the pedicle area appearing flat and yielding a satisfactory aesthetic contour, thereby improving the overall postoperative appearance.

The pedicle of a distally based flap is crucial for both arterial supply and venous drainage. Most scholars currently consider circulatory compromise a primary cause of necrosis in distally based or reverse-flow island flaps, underscoring the importance of proper pedicle management[14]. Inadequate handling can lead to either arterial insufficiency or venous congestion, resulting in partial or complete flap loss. While conventional venous flow is typically distal-to-proximal, it often reverses in distally based flaps. This reverse flow predisposes the flap to congestion and partial necrosis. Moreover, veins, being less elastic than arteries, are more prone to obstruction under increased pressure[10]. Voche et al., in a series of 41 lateral supramalleolar flaps, observed venous drainage issues in 8 cases, including 3 instances of partial necrosis (5%-30%)[15]. Lin noted that even early surgical exploration might lead to irreversible damage and eventual flap loss[5].

To address venous return, Herlin et al. employed venous supercharging, although the procedure is relatively cumbersome[16]. Some scholars posit that venous drainage in distally based flaps is related to pedicle handling, suggesting that preserving a skin bridge during pedicle harvesting and using a loose, open tunnel can effectively alleviate congestion and swelling, thereby promoting flap survival [11]. Based on an anatomical study of venous return in the sural flap, Loonen et al. proposed preserving a 3.5 cm wide skin strip over the pedicle to minimize vascular compression and ensure safe venous return[17]. Noack designed a "tail-shaped" skin extension at the pedicle to act as a roof for an open tunnel, alleviating pressure on the pedicle vessels and preventing venous obstruction[18]. David suggested that simply increasing flap width does not ensure hemodynamic safety; instead, increasing pedicle thickness to include more subcutaneous vasculature is more beneficial for the flap[19].

Building upon previous research, we modified the pedicle design. In our study, a mini-flap was preoperatively designed at the vascular pedicle, and during flap elevation, a 2–5 cm wide fascia tissue was preserved along the vascular pedicle. This pedicle mini-flap helps maintain the pedicle in a more natural physiological state, incorporates more subcutaneous vasculature to enhance circulation, and its larger volume distributes torsional and compressive forces over a broader tissue area rather than concentrating them solely on the pedicle. Isao advocated preserving only the supplying artery and its concomitant vein

in the pedicle, routinely excising all fascial tissue under a surgical microscope to prevent postoperative soft tissue edema from compressing the pedicle vessels and causing flap necrosis[20]. Conversely, other scholars hold the opposing view, emphasizing that during pedicle dissection for a distally based flap, the vascular pedicle and its branches must be meticulously included, preserving ample perivascular tissue to avoid compromising flap viability. They suggested designing the pedicle into a triangular shape to fully cover the vascular channel during flap transposition [21]. In our clinical practice, we found that complete stripping of perivascular tissue significantly increases surgical risk. Preserving more soft tissue, by contrast, reduces operative trauma and associated risks. Furthermore, minimized manipulation of the pedicle vessels can help prevent vasospasm. In our experience, less aggressive pedicle dissection results in a smoother learning curve for this flap procedure, making it more accessible for surgeons to learn and perform.

This study has several limitations that should be acknowledged. First, its retrospective, non-randomized design inherently carries selection bias, as the decision to design a pedicle mini flap was at the surgeon's discretion and may have been influenced by intraoperative findings or patient-specific factors. Second, the sample size is relatively modest (78 patients total), and the study was not powered to detect small differences in complication rates; the lack of statistical significance for some outcomes may reflect Type II error rather than

true equivalence. Third, all surgeries were performed by a single surgeon at a single institution, which limits the generalizability of our findings to other settings or surgeons with different levels of experience. Fourth, we did not perform multivariate logistic regression analysis to identify independent risk factors for venous congestion, nor did we objectively assess venous congestion using quantitative tools such as near-infrared spectroscopy or laser Doppler flowmetry. Fifth, the follow-up period (minimum 12 months) is adequate for flap survival assessment but insufficient for long-term functional and aesthetic outcomes, particularly in load-bearing areas. Sixth, we did not record operative time or hospital stay, which are important parameters for evaluating the clinical efficiency of this technique. Finally, the classification and severity of flap necrosis were not independently assessed by a blinded evaluator, introducing potential assessment bias.

Conclusion

In summary, Both distally based flaps and pedicled mini-flaps are safe and effective for large skin defects, yet they also carry a degree of risk for vascular compromise. Compared to conventional distally based flap surgery, designing a pedicle mini-flap may reduce the risk of pedicle kinking or external compression, and it simplifies flap elevation by preserving a wider fascial pedicle, potentially lowering the learning curve. This technique offers advantages such as easier execution and a flat, aesthetically pleasing

postoperative appearance. It represents a potential method for preventing circulatory compromise in distally based flaps.

Reference

1. Jia S, Huang J, Lu W, et al. Global hotspots and future directions for drugs to improve the skin flap survival: A bibliometric and visualized review. *J Pharm Anal*. 2024;14:100948.

2. Touam C, Rostoucher P, Bhatia A, et al. Comparative Study of Two Series of Distally Based Fasciocutaneous Flaps for Coverage of the Lower One-Fourth of the Leg, the Ankle, and the Foot: *Plastic and Reconstructive Surgery*. 2001;107:383–392.

3. Woo SJ, Kang J, Hu JL, et al. Medial Plantar Fasciocutaneous Flap Reconstruction for Load-Bearing Foot Defects in Patients With Acral Melanoma. *Ann Plast Surg*. 2022;88:658–664.

4. Li Y, Jiang Q, Van Der Merwe L, et al. Preclinical efficacy of stem cell therapy for skin flap: a systematic review and meta-analysis. *Stem Cell Res Ther*. 2021;12:28.

5. Follmar KE, Baccarani A, Baumeister SP, et al. The Distally Based Sural Flap: *Plastic and Reconstructive Surgery*. 2007;119:138e–148e.

6. Hallock GG. Distally Based Flaps for Skin Coverage of the Foot and Ankle. *Foot Ankle Int*. 1996;17:343–348.

7. Donski PK, Fogdestam I. Distally Based Fasciocutaneous Flap from the Sural Region. *Scandinavian Journal of Plastic and Reconstructive Surgery*. 1983;17:191–196.

8. De Blacam C, Colakoglu S, Ogunleye AA, et al. Risk factors associated with complications in lower-extremity reconstruction with the distally based sural flap: A systematic review and pooled analysis. *Journal of Plastic, Reconstructive & Aesthetic Surgery*. 2014;67:607–616.

9. Lin C, Zelken J, Hsu C, et al. The distally based, venous supercharged anterolateral thigh flap. *Microsurgery*. 2016;36:20–28.

10. Boissiere F, Gandolfi S, Riot S, et al. Flap Venous Congestion and Salvage Techniques: A Systematic Literature Review. *Plastic and*

Reconstructive Surgery - Global Open. 2021;9:e3327.

11. Lagvankar SP. Distally-based random fasciocutaneous flaps for multi-staged reconstruction of defects in the lower third of the leg, ankle and heel. *British Journal of Plastic Surgery*. 1990;43:541–545.

12. Lin R, Lin J, Li S, et al. Effects of the traditional Chinese medicine baicalein on the viability of random pattern skin flaps in rats. *DDDT*. 2018;Volume 12:2267–2276.

13. Khoo ET, Al-Chalabi MMM, Mat Johar SFN, et al. Medial Gastrocnemius Tenocutaneous Island Flap: A Salvage Option After Free Flap Compromise in the Lower Limb. *Cureus*. 2024.

14. Schmidt K, Jakubietz M, Meffert R, et al. The reverse sural artery flap–How do modifications boost its reliability? A systematic analysis of the literature. *JPRAS Open*. 2020;26:1–7.

15. Voche P, Merle M, Stussi J-D. The Lateral Supramalleolar Flap: Experience With 41 Flaps. *Annals of Plastic Surgery*. 2005;54:49–54.

16. Herlin C, Bekara F, Bertheuil N, et al. Venous Supercharging Reduces Complications and Improves Outcomes of Distally Based Sural Flaps. *J reconstr Microsurg*. 2017;33:343–351.

17. Loonen MPJ, Kon M, Schuurman AH, et al. Venous Bypass Drainage of the Small Saphenous Vein in the Neurovascular Pedicle of the Sural Flap: Anatomical Study and Clinical Implications: *Plastic and Reconstructive Surgery*. 2007;120:1898–1905.

18. Noack N, Hartmann B, Küntscher MV. Measures to Prevent Complications of Distally Based Neurovascular Sural Flaps: *Annals of Plastic Surgery*. 2006;57:37–40.

19. Hom DB, Ostrander BT. Reducing Risks for Local Skin Flap Failure. *Facial Plastic Surgery Clinics of North America*. 2023;31:275–287.

20. Koshima I, Narushima M, Mihara M, et al. Island Medial Plantar Artery Perforator Flap for Reconstruction of Plantar Defects. *Annals of Plastic Surgery*. 2007;59:558–562.

21. Pu LLQ. Locoregional Flaps in Lower Extremity Reconstruction. *Clinics in Plastic Surgery*. 2021;48:157–171.

Funding

The authors received no specific funding for this work.

Clinical trial number

Not applicable.

Figure legend list

Fig. 1 Schematic representation of the pedicle mini flap. (a) The distally based flap was designed to be larger than the wound. (b) A mini flap was designed at the pedicle of the distally based flap. (c) Skin defect. (d) The pedicle of the flap. (e) Subcutaneous passage of the pedicle of the flap.

Fig. 2 Two patient treated with distally based flap with design pedicle mini flap. (A~C) The distally based flap was designed to the patient with dorsalis pedis skin defect, and the pedicled mini flap was designed. (D~F) For a patient with an exposed tibialis anterior tendon, a distally based flap with pedicle mini flap was designed to cover the wound.

Fig. 3 Two patient treated with distally based flap. (A~C) A distally based peroneal artery flap was designed to cover the wound in a patient with post-traumatic peroneal tendon exposure. (D~F) For a patient with a lateral calcaneal wound with bone exposure, a distally based sural neuro-fasciocutaneous flap was designed to cover the wound. Red arrow, partial flap had poor blood supply.

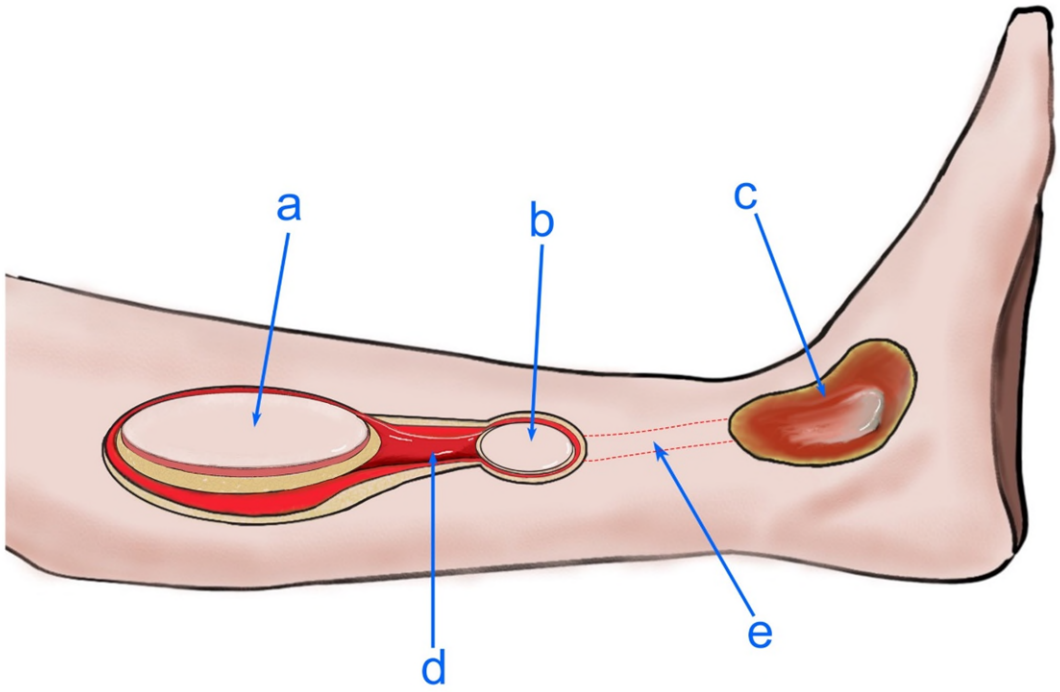


Fig. 1 Schematic representation of the pedicle mini flap. (a) The distally based flap was designed to be larger than the wound. (b) A mini flap was designed at the pedicle of the distally based flap. (c) Skin defect. (d) The pedicle of the flap. (e) Subcutaneous passage of the pedicle of the flap.

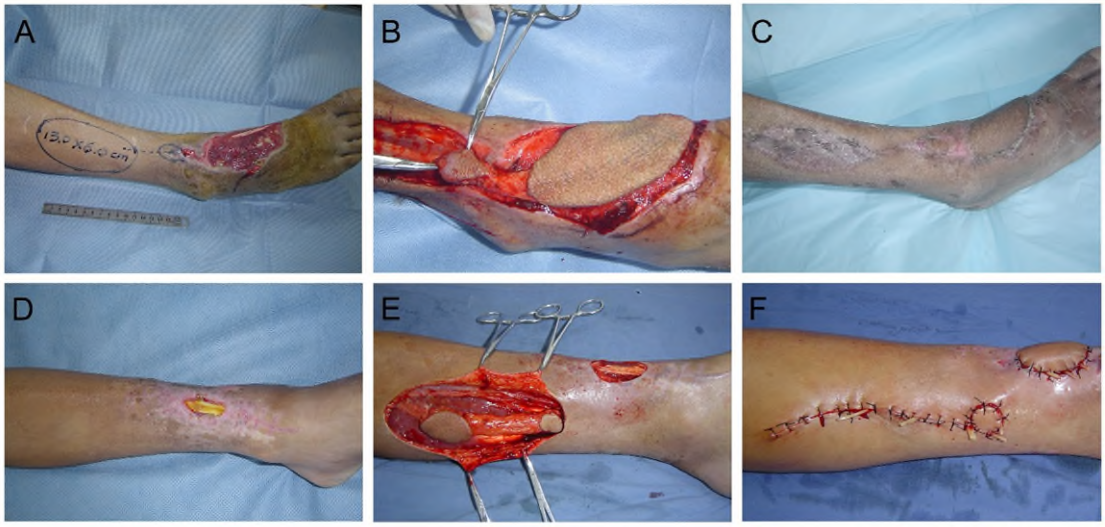


Fig. 2 Two patient treated with distally based flap with design pedicle mini flap. (A~C) The distally based flap was designed to the patient with dorsalis pedis skin defect, and the pedicled mini flap was designed. (D~F) For a patient with an exposed tibialis anterior tendon, a distally based flap with pedicle mini flap was designed to cover the wound.

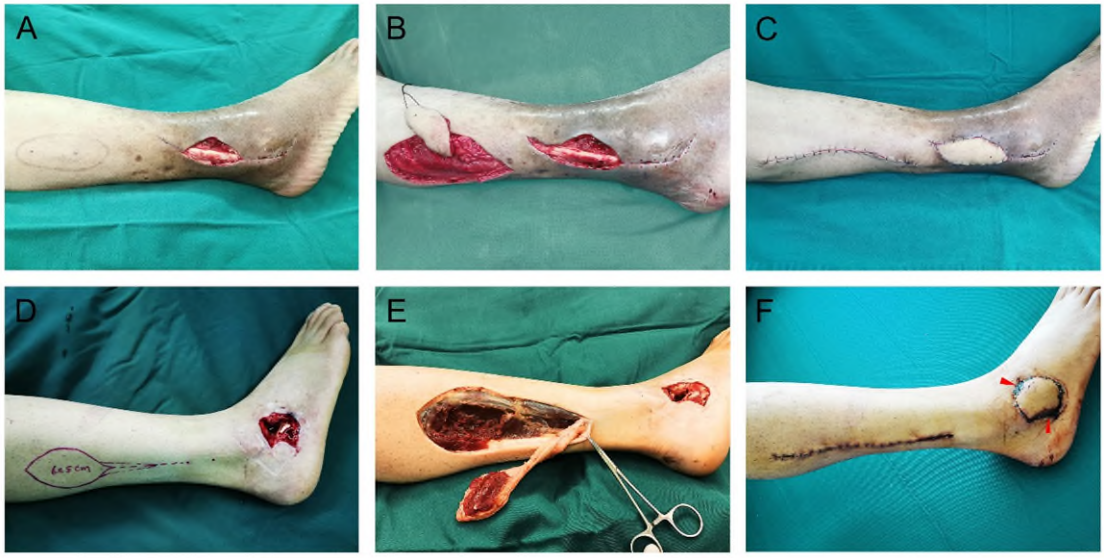


Fig. 3 Two patient treated with distally based flap. (A~C) A distally based peroneal artery flap was designed to cover the wound in a patient with post-traumatic peroneal tendon exposure. (D~F) For a patient with a lateral calcaneal wound with bone exposure, a distally based sural neurofasciocutaneous flap was designed to cover the wound. Red arrow, partial flap had poor blood supply.

Supplementary Files

This is a list of supplementary files associated with this preprint. Click to download.

- Table1.docx
- Table2.docx
- Table3.docx