

Should Every Mummified Toe Be Amputated? Toe Preservation With a Perforator Flap

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Background: Peripheral gangrene, caused by various etiologies, including diabetes, peripheral artery disease, trauma, and vasopressor use, poses significant challenges. Traditional management often involves proximal amputation, which carries a high risk of major amputation and mortality. This study evaluated the efficacy of perforator flaps for toe preservation in patients with toe necrosis.

Methods: Six patients with peripheral gangrene, affecting a total of 9 toes, were retrospectively analyzed. The surgical procedure entailed only soft tissue debridement with minimal to no bone amputation and subsequent coverage using thin perforator flaps. Patient demographics, surgical details, flap outcomes, and additional procedures were also reviewed.

Results: Despite potential technical challenges, all but 1 flap survived, with 1 patient requiring partial flap loss management using a full-thickness skin graft. Most patients exhibited successful infection control and wound healing, with a significant emphasis on preserving toe functionality and length.

Conclusions: This study demonstrated that toe preservation with “encircling” perforator flaps is a viable alternative to traditional proximal amputation for patients with peripheral gangrene. This approach may provide a potential benefit in preserving limb length, but careful patient selection and surgical precision are paramount for achieving favorable outcomes. (*Plast Reconstr Surg Glob Open* 2025;13:e6564; doi: 10.1097/GOX.00000000000006564; Published online 3 March 2025.)

INTRODUCTION

Peripheral gangrene, which has diverse etiologies, such as diabetes, peripheral artery disease, trauma, and vasopressor use, is a well-recognized clinical entity.^{1,2} Standard surgical management involves proximal amputation above the necrotic tissue to facilitate subsequent wound closure. However, minor amputations may be associated with a substantial risk of major amputation and mortality. A study reported that 1 in 10 patients undergo ipsilateral

major amputation within the initial year following a minor amputation, and half of them experience mortality within 5 years.³ Consequently, proactive therapeutic strategies for this condition are imperative for medical necessity as well as long-term patient survival.

Recent advancements in orthopedics and microsurgery have introduced extreme limb salvage techniques followed by free-flap reconstruction. These innovative approaches are designed to reduce the risk of major amputations and promote rapid rehabilitation for patients with severe limb injuries. By using these techniques, surgeons aim to preserve as much of the patient’s limb as possible, thus enhancing functional outcomes and improving the quality of life after surgery.

Despite the favorable functional outcomes associated with extreme limb salvage techniques, reports specifically addressing toe preservation are sparse in the literature. Toe preservation remains a significant challenge due to the technical difficulties and high costs associated with these procedures. Consequently, toe amputation is often chosen when necrosis occurs, as it is simpler and more cost-effective.

The limited literature on toe preservation highlights a gap in the current understanding and underscores the need for further research in this area. Developing more

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effective strategies for toe preservation could significantly enhance patient outcomes, offering better function and quality of life after surgery. This study aimed to address this concern by implementing a method focused on toe preservation involving meticulous soft tissue debridement while conserving select bone segments, minimizing or avoiding amputation, and encircling the affected area with a thin perforator flap.

PATIENTS AND METHODS

This retrospective study was conducted in accordance with ethical guidelines and approved by the institutional ethics committee of Ewha Womans University Hospital in Korea (approval number: 2023-12-019). The surgical procedure was performed in a total of 6 cases, involving 8 affected toes, selected based on specific indications. These indications encompassed the following criteria: (1) relatively recent onset of necrosis, (2) systemic conditions that were amenable to general anesthesia at the time of surgery, and (3) patients presenting with necrosis affecting either the first or second toe. In 2 additional cases of peripheral artery obstruction, surgery was initially planned based on the same indications; however, the procedure ended with minor amputation due to the status of the vessels.

Preoperative evaluation involved the use of computed tomography angiography to assess the recipient vessel status. In cases where the patient had previously undergone percutaneous transluminal angioplasty, the available imaging data were helpful in guiding the surgical approach. Furthermore, a simple radiographic examination of the affected toes was performed as a routine preoperative step. Radiographic findings of advanced toe bone deterioration, such as the presence of radiolucent lesions or fracture signs, indicate a loss of bone density or advanced osteomyelitis. These findings may pose challenges to toe

Takeaways

Question: Should every mummified toe be amputated, or can perforator flaps preserve the toe?

Findings: Soft tissue debridement followed by perforator flap coverage was performed. Most flaps survived, achieving successful infection control and wound healing while preserving toe functionality and length.

Meaning: Perforator flaps can effectively preserve mummified toes, reducing the need for amputation and improving recovery outcomes.

preservation, and therefore, indications and individualized adaptations for each patient should be established before surgery. Intraoperatively, after applying K-wire fixation to the necrotic toe, only soft tissue debridement, in a manner similar to paring an apple, was performed on the entire necrotic tissue. When abnormal bone was observed distally, partial debridement was performed.

The recipient vessel, including the superficial veins, was prepared in the proximal area of the dorsum of the foot. Although the choice of the flap was dependent on the surgeon's preference, close attention was needed to design the flap precisely. Because of the requirement for encirclement by the flap of a cylindrical bone (Fig. 1), the thickness of the flap was carefully controlled, as the actual required area often exceeds the initial estimation using a thin flap. Moreover, a pedicle longer than initially anticipated is usually required with the inseting encircling the flap. When we resurfaced more than 1 toe, we created a mitten with a perforator flap and performed a division procedure after several weeks of coverage (Fig. 2). The K-wire was retained for a period of 3–4 weeks to ensure proper stabilization and healing of the affected area.



Fig. 1. Photographs of a 55-year-old man with diabetes who experienced total occlusion of the common femoral artery (case 6). A, Preoperative photograph of the necrotic great toe. B–D, Postoperative photographs showing the anterolateral thigh flap covering the preserved bone.



Fig. 2. Photographs of the foot of a 61-year-old man after traumatic injury (case 2). A, Necrosis of multiple toes. B, After soft tissue-only debridement (paring the necrotic tissue) and K-wire insertion, the bones were completely preserved. C, Intraoperative photograph of the anterolateral free flap. D and E, Immediate postoperative photographs showing the creation of a mitten for coverage. F, Follow-up photograph at 30 months after division.

RESULTS

Six patients, with a mean age of 57.3 years (range 48–72 y), underwent limb-length preservation procedures focused on toe preservation using free-flap reconstruction. The mean follow-up time was 39.0 months (range 14–72 mo). The cohort included 4 male (66.7%) and 2 female (33.3%) patients with a mean body mass index of 30.3 (range 22.4–35.7) kg/m². Among them, 4 (66.7%) were smokers, and 2 (33.3%) were nonsmokers.

Comorbidities were present in 5 (83.3%) patients, including 3 with diabetes, 2 with coronary artery occlusive disease, and 2 with peripheral artery occlusive disease. The most common etiology was trauma (2 patients, 33.3%), followed by peripheral artery occlusive disease (2 patients, 33.3%), and diabetes (1 patient, 16.7%).

The types of flaps used included 3 thoracodorsal artery perforator free flaps and 3 anterolateral thigh free flaps. The vascular anastomoses were predominantly performed

Table 1. The Study Data

	Etiology	Location	Recipient Vessels	Kinds of Flap	Flap Outcome	Additional Procedure	Follow-up (mo)
1	Diabetic Foot	Great toe	Dorsal digital artery	Thoracodorsal artery perforator free flap	Survived	Debulking	72
2	Trauma	Great toe and second toe	First dorsal metatarsal artery	Anterolateral thigh free flap	Survived	Division operation	70
3	Trauma	Great toe and second to fourth toes	First dorsal metatarsal artery	Anterolateral thigh free flap	Survived	Division operation	30
4	PAOD	Great toe and second toe	First dorsal metatarsal artery	Thoracodorsal artery perforator free flap	Survived	None	24
5	PAOD	Great toe	Dorsalis pedis artery	Thoracodorsal artery perforator free flap	Partial loss	Full-thickness skin graft	24
6	PAOD (proximal level obstruction: superficial femoral artery)	Great toe	Dorsal digital artery	Anterolateral thigh free flap	Survived	None	14

PAOD, peripheral artery obstructive disease.



Fig. 3. Radiographic evaluation of the salvaged toe following soft tissue coverage with a flap. A, Immediate postoperative x-ray showing the initial alignment and stabilization of the salvaged toe. B, x-ray taken 3 months postoperatively, demonstrating maintained alignment and bony survival.

with the first dorsal metatarsal artery or the dorsal digital artery. Of the 6 cases, 3 (50.0%) required additional procedures, such as division operations or debulking (Table 1).

Flaps survived in 5 (83.3%) patients, whereas partial flap loss occurred in 1 (16.7%) patient, necessitating a full-thickness skin graft. No total flap losses were reported (Table 1). Long-term follow-up imaging, including x-rays, was performed on all patients. These radiographs showed good alignment and bony survival of the nonvascularized toe bones covered by the flaps (Fig. 3), indicating successful preservation of both soft tissue and bone integrity in these patients.

DISCUSSION

Extremity necrosis, which has a multifactorial etiology, has been increasingly observed following vasopressor administration. Progression to an irreversible stage,

commonly referred to as “mature necrosis” or “dry gangrene,” often necessitates amputation, a critical yet impactful intervention aimed at removing nonviable tissue to prevent systemic complications.⁴ Despite its necessity, amputation carries substantial functional and psychosocial consequences for patients.³

The surgical landscape for managing extremity necrosis is shifting toward limb salvage techniques.⁵ Recent literature highlights the use of perforator flaps as a viable alternative to digital amputation, emphasizing the preservation of limb functionality and aesthetics.^{6,7} Limb salvage, particularly through minor amputations, such as transmetatarsal amputation combined with free-flap coverage, has emerged as a superior option in terms of limb salvage rates.⁸ This approach offers functional and aesthetic benefits while underscoring the necessity of meticulous patient selection and technical proficiency. However, the application of limb preservation strategies for toe preservation

remains limited and challenging. Toe preservation is not considered essential, leading to a scarcity of necessities and surgical techniques. However, recent necrosis confined to the small bones of the distal toe may frequently allow for coverage without amputation. This distinction emphasizes the importance of precise determination of surgical indications and tailored therapeutic strategies for optimizing outcomes.

In our series, 3 patients presented with necrosis confined to the great toe only, whereas the other 3 cases involved both the great and second toes. Except for 1 partial loss, the flap survived in all cases. For patients with 2-toe involvement, a mitten-shaped flap was used to enclose the toes, followed by a division operation performed between 1.5 and 3 months later. Among the patients, 3 had diabetes, and 3 underwent percutaneous transluminal angioplasty before surgery.

The success of these procedures is closely linked to meticulous control of the flap thickness. When flap thickness posed a challenge to adequately wrapping the affected area, primary flap thinning was performed to ensure optimal results. Crucially, the precise design of the flap to conform to the 3-dimensional structure of the defect area—considering the flap dimensions and pedicle position—was pivotal in achieving successful outcomes.

Recipient vessel selection often involves small distal vessels, with the dorsal digital artery or dorsal metatarsal artery being a particularly convenient choice for pedicle placement. However, the small caliber of these vessels demands meticulous attention during microanastomosis to ensure a secure and functional connection. Additionally, the use of superficial veins was explored as a viable option for venous anastomosis, offering a secure connection with large-caliber veins, which can enhance the overall success of the flap.

Our concept emphasizes soft tissue debridement and free-flap coverage, following minimal amputation when needed or complete or near-complete bony salvage of the necrotic toe. The established efficacy of perforator flaps, owing to their superior blood supply for addressing inflammation and osteomyelitis, lays the foundation for this approach. Bony discontinuity is restored using well-vascularized perforator flaps in patients with osteomyelitis.⁹

Based on this knowledge, we assumed that for relatively recent cases of necrosis, the degree of bony viability could be addressed through microvascular free-flap coverage with well-vascularized tissue. Nevertheless, despite careful preoperative planning and identification of specific indications, toe preservation as initially planned is not always feasible because of unforeseen bony problems or vascular complications. Additionally, the inherent technical demands and challenges of objectively assessing bone viability owing to the small size of the involved bones represent notable limitations of this approach. When favorable diagnostic imaging was performed, intraoperative findings revealed compromised bone integrity, necessitating minor amputation followed by coverage.

Microvascular techniques are advancing, and reconstruction has now achieved perfection, even in more

distal regions. Various toe defects can be treated without amputation, and peripheral gangrene can be successfully managed from this new perspective. This evolution in microsurgical capabilities has expanded the possibilities of limb salvage, pushing the boundaries of what can be preserved and restored. Our method used debridement of only soft tissue and free-flap coverage after either minimal amputation of the necrotic area or complete salvage. It is well-established that flaps, which have excellent circulatory properties, can be successfully applied to facilitate wound healing. Integrating these advanced microvascular and reconstructive techniques not only improves the quality of life of patients but also redefines the standards of care in limb preservation. Future research and clinical trials are essential to further refine these approaches, optimize patient outcomes, and establish standardized protocols for the broader application of these techniques in complex cases of limb and digit preservation.

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