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Reconstruction of Lateral Malleolar Defects: Adipofascial Turnover Flap Based on the Peroneal Artery Perforator

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Abstract

Background: Lateral malleolar defects are a commonly encountered clinical issue, with several treatment options available from local flaps to microsurgical reconstruction. However, ankle defects are difficult to manage, especially in patients with comorbidities. We report here our experience of lateral malleolar reconstruction using adipofascial turnover flaps based on the peroneal artery perforator.

Methods: A total of nine patients who underwent peroneal artery perforator-based adipofascial turnover flap coverage from December 2011 to February 2016 were retrospectively evaluated. Data were collected on the patients' age, sex, etiology, comorbidities, anesthesia type, combined surgery, presence of osteomyelitis, bacterial profiles, vascular status, defect size, flap size, flap elevation time, follow-up period, and complications.

Results: The mean age of the patients was 66.4 years. The most common cause of the wound was pressure injury. Seven patients had one or more comorbidities, and four patients were current smokers. Three patients were diagnosed with chronic osteomyelitis. Percutaneous transluminal angioplasty was performed in two patients. The mean defect size was 8.4 cm^2, and the mean follow-up period was 30.7 months. All nine flap transfers were successful without major complications. However, in one case, partial skin graft loss occurred, requiring additional skin grafting.

Conclusion: The peroneal artery perforator-based adipofascial turnover flap is a safe and reliable method to reconstruct lateral malleolar defects. The operative technique is simple and convenient to perform and hence a useful option for reconstructing lateral malleolar defects. This is especially true for patients with comorbidities who are typically not indicated for more complex procedures.

Keywords: Surgical flaps; Perforator flap; Reconstructive surgical procedures; Lower extremity

Introduction

Defects in the malleolus region are commonly encountered in clinical practice and can be attributed to various causes such as trauma, pressure injuries, and diabetes. Superficial defects can be treated with conservative methods such as dressings, but full-thickness defects are not easy to treat. This is because even small-sized skin defects are usually accompanied by widely undermined pockets of subcutaneous tissue defects, which makes the process of epithelization difficult. Friction caused by joint motion, leakage of joint fluid, chronic serous discharge due to infections, and concomitant infections such as bursitis or osteomyelitis are other common obstacles to secondary intention healing in this region [1].

In many cases of foot and ankle defects, reconstruction is difficult as the areas often have poor circulation due to diabetes, peripheral vascular disease, etc., and ligament or bone exposure is common, and there is insufficient tissue that can be used around the defect. Microsurgical reconstruction is a good option for foot and ankle recon-

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struction, but as it is costly and requires microsurgical equipment, local flap reconstruction is also widely performed [2].

The distally based sural flap procedure has been commonly used since it was first reported by Masquelet et al. in 1992 [3], and a meta-analysis of all 50 articles that report the use of the unmodified distally based sural flap was performed by Follmar et al. in 2007 [4]. Many modifications of the procedure have been reported aiming to reduce complications and increase the success rate, such as the delay technique [5], supramalleolar flap [6], retromalleolar flap [7], and peroneal artery perforator flap [8].

In lateral malleolar defects which are challenging to manage, we have applied one of these modifications: the adipofascial turnover flap based on a peroneal artery perforator. Although most of our cases were patients in medically compromised patients with comorbidities, all flap transfers were successful without major complications. This study aims to describe our experience of this technique and discuss the advantages and limitations of the strategy.

Methods

Patients

We recruited patients who had a defect in the lateral malleolar area reconstructed with a distally based sural adipofascial turnover flap based on a peroneal artery perforator between December of 2011 and February of 2016. The operations were performed by a single surgeon (HJY). All data were acquired from retrospective chart review following approval by the Institutional Review Board (IRB No. DFE21ORIO108, 2021-09-027). This study conformed to the World Medical Association Declaration of Helsinki (June 1964) and its subsequent amendments. Informed consent was exempted due to the retrospective design of the study. Data were collected on patient age, sex, etiology, comorbidities, anesthesia type, combined surgery, presence of osteomyelitis, bacterial profiles, defect size, flap size, flap elevation time, follow-up period, and complications.

Surgical technique

For patients without palpable peroneal artery on physical examination or with possible vascular injury due to previous trauma, computed tomography (CT) angiography for the lower extremities was performed and, if indicated prior to surgery, percutaneous transluminal angioplasty (PTA) was performed. The peroneal artery perforators were mapped using hand-held Doppler ultrasonography the day before the operation. Surgery was performed under spinal anesthesia if possible. However, if spinal anesthesia was difficult or in cases where a combined operation on other areas was required, general anesthesia was used. In cases where the patient had high anesthesia-related risk due to poor general condition, local anesthesia was used. For general or spinal anesthesia, a tourniquet was applied, and for local anesthesia, 1:100,000 epinephrine mixed with 1% lidocaine was infiltrated into the surgical site. After thorough debridement of the necrotic and scar tissues and unhealthy bone tissue, the size of the soft-tissue defect was measured.

The posterior border of the fibula and the lateral border of the Achilles tendon were marked, respectively. Since the peroneal perforator exists within this range, the flap width was designed to not exceed this range. The perforator was rechecked and marked using a hand-held Doppler, and the pivot point was determined (Fig. 1A). The width of the flap was designed to be identical to the width of the defect, and the length of the flap was determined by using a piece of gauze to simulate flap turnover and insetting for satisfactory coverage of the defect; the flap was designed to be a little longer considering the thickness of the folded part of the flap (Fig. 1B and C).

A longitudinal skin incision was made in the middle of the designed flap, and skin flap elevation was performed on both sides of the incision. At this point, to prevent flap necrosis of the donor site, about 2–3 mm of fat tissue was included in the skin flaps, and to reduce thermal injury, these were dissected using a sharp device such as a scalpel or scissors rather than an electrocautery device (Fig. 1D). The adipofascial flap was elevated to the previously designed pivot point by dissecting below the deep fascia (Fig. 1E). The flap was then turned over to cover the defect without tension. The flap was subsequently inset into the defect and fixed with absorbable sutures. For cases with subcutaneous tunneling under the skin margins of the wound, the sutures were passed into the undermined pocket, brought out through the skin, and tied over sponge bolsters to reduce dead space. The flap was then covered with a split-thickness skin graft. The skin graft was fixed with 5-0 nylon, and a wet-to-dry dressing was applied without pressure to prevent compression of the flap. A negative drain was placed in the donor site and primary closure was performed (Fig. 1F). A short leg splint was applied for immobilization, and elevation of the leg was required for 2 weeks postoperatively to reduce edema and prevent venous congestion.

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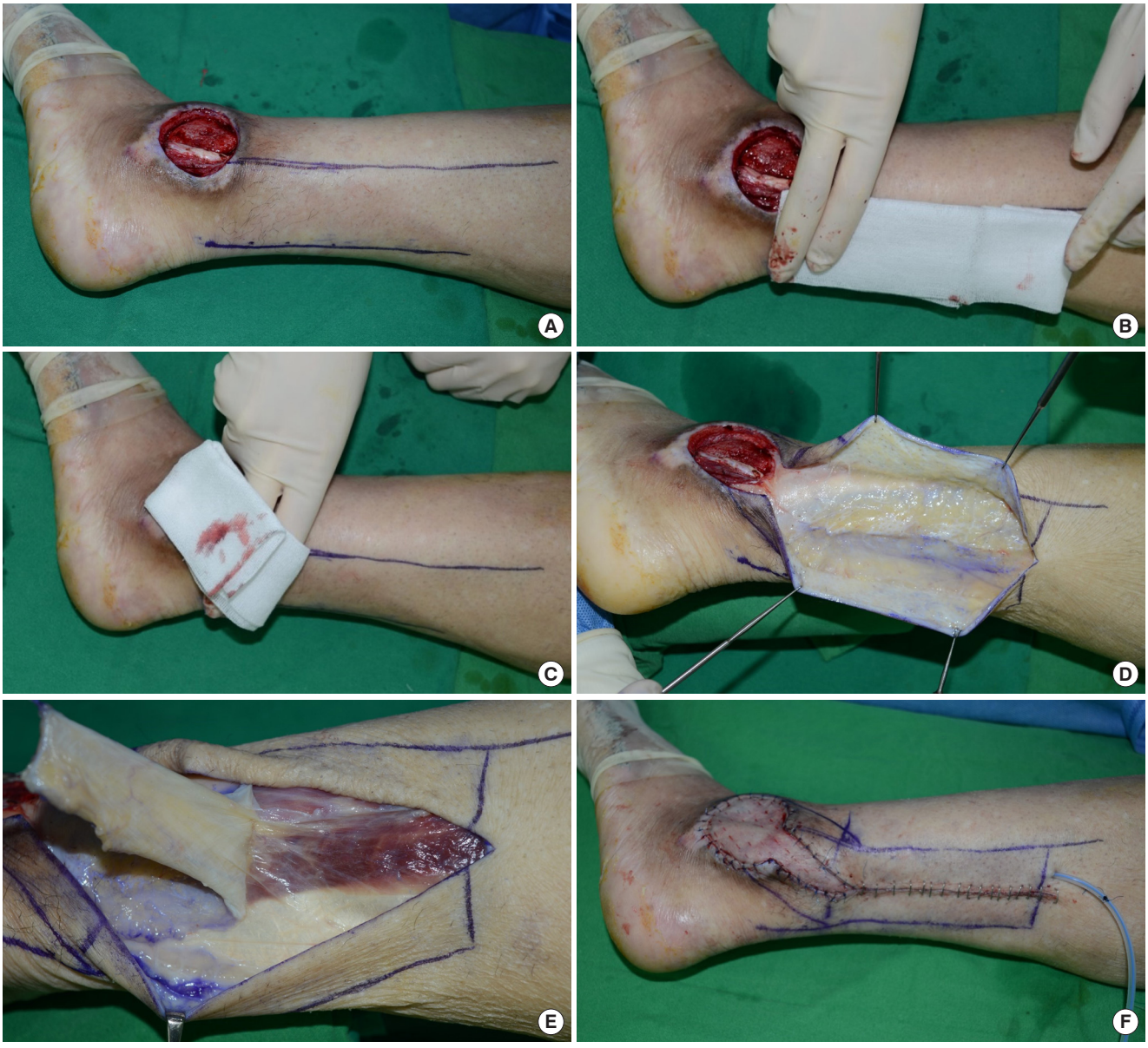

Fig. 1. Surgical technique of the adipofascial turnover flap. (A) Preoperative photograph. Peroneal tendon was exposed. (B, C) The flap length could be determined using folded gauze. The pivot point was also marked. (D) Skin flap elevation. (E) Elevation of adipofascial flap. (F) Immediate postoperative photograph.

Results

Data are listed in Table 1. All nine patients were male. The patients' ages ranged from 48 to 80 years old (mean, 66.4 years old). In four patients, the defects were caused by pressure sores, while in two other patients, they were postoperative wounds following mass excision done at other clinics. In two other cases, the defects were caused by diabetic foot ulcers. In one patent, it was caused by trauma. Seven out of the nine patients had one or more comorbidities, and four out of nine were current smokers. Three out of nine patients were diagnosed with chronic osteomyelitis from a three-phase bone scan. Wound swab cultures were performed before the operation. In seven out of nine patients, no microorganisms were identified from the wound. Vancomycin-susceptible *Enterococcus* and *Providencia stuartii* were identified in one patient. *Mycobacterium tuberculosis* was identified in another. CT angiography of the lower extremities was performed in six pa-

Table 1. Patient demographics and clinical information

Patient no.	Sex/age (yr)	Etiology	Comorbidities	Anesthesia type	Combined surgery	Presence of osteomyelitis	Bacterial profile	Wound size (cm^2)	Defect size (cm^2)	Flap size (cm^2)	Flap elevation time (min)	Follow-up period (mo)	Complications
1	M/71	Pressure sore	HTN, DM, CVA	General		Not examined	No microorganism	NR	15.75	44	53	2	
2	M/72	Pressure sore	Dementia	General	Combined sacral sore operation	Not examined	No microorganism	4	4	36	77	2	
3	M/73	Pressure sore	HTN	General	Combined sacral sore operation	Not examined	VSE, *Providencia stuartii*	4	4	32	52	1	
4	M/80	Pressure sore	IHD, PAOD	Local		+	No microorganism	1.5	9	33.25	NR	55	
5	M/66	Diabetic foot ulcer	HTN, DM, CVA, ESRD	Spinal		−	No microorganism	4	12	44	53	14	Cellulitis
6	M/58	Diabetic foot ulcer	HTN, DM, LC, ESRD	Local		+	No microorganism	0.4	9	60	NR	61	
7	M/48	Postoperative defect		Spinal		−	*Mycobacterium tuberculosis*	9	9	52	NR	90	
8	M/73	Postoperative defect	IHD	Spinal		+	No microorganism	4	7	36.75	58	2	
9	M/57	Trauma		General	Combined fasciocutaneous flap (tibial side)	−	No microorganism	6	6	16	24	49	Skin graft loss
Mean	66.4							2.5	8.4	39.3	52.8	30.7	

M, male; HTN, hypertension; DM, diabetes mellitus; CVA, cerebrovascular accident; IHD, ischemic heart disease; PAOD, peripheral artery occlusive disease; ESRD, end-stage renal disease; LC, liver cirrhosis; VSE, vancomycin-susceptible *Enterococcus*; NR, not recorded.

tients and PTA was performed in two patients prior to the surgery. Seven out of nine patients underwent surgery with general or spinal anesthesia, and two patients with poor general condition underwent surgery with local anesthesia. While one of the patients had thrombocytopenia due to liver cirrhosis, there were no difficulties in controlling the bleeding even without a tourniquet. The defect size after debridement ranged from 2×2 cm to 4.5×3.5 cm (mean, 8.4 cm^2). The size of the flaps ranged from 8×2 cm to 15×4 cm (mean, 39.3 cm^2). The flap elevation time was measured in six patients at 24 to 77 minutes (mean, 52.8 minutes).

The follow-up period ranged from 1 to 90 months (mean± standard deviation, 30.7±31.6 months). Complications occurred in two out of nine patients. One patient had partial loss of the skin graft, and an additional split-thickness skin graft was performed 2 weeks after surgery. The other patient developed cellulitis 3 months after surgery and improved after administration of oral antibiotics. Other than those problems, there were no complications such as total or partial flap loss, venous congestion, dehiscence, or necrosis. During the postoperative follow-up period, no patient had difficulty in shoe fitting or required revision due to flap bulk.

Case 1 (patient no. 1)

A 71-year-old male patient visited the hospital because of a pressure sore in the left lateral malleolus with purulent discharge that did not heal for several months. He had hypertension, diabetes mellitus, and history of a previous cerebellar infarction. The operation was performed under general anesthesia without a tourniquet. After radical debridement of necrotic tissues and unhealthy bone tissues, the defect was measured to be 4.5×3.5 cm. An adipofascial turnover flap was elevated and inset in the defect. As tunneling was observed around the skin defect, flap-anchoring sutures were passed into the pocket, brought out through the skin, and tied over sponge bolsters (Fig. 2).

Case 2 (patient no. 4)

An 80-year-old male patient visited the hospital because of a pressure sore in the right lateral malleolus that did not heal despite conservative treatment for 2 years. The patient had a medical history of ischemic heart disease and peripheral artery occlusive disease. The operation was performed after local infiltration without tourniquet due to a high risk of general anesthesia. After debridement, the defect size was 3.0×3.0 cm, and the flap size was designed to be 9.5×3.5 cm. It was recon-

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Fig. 2. A 71-year-old male patient with a left lateral malleolar defect. (A) Preoperative photograph. (B) After debridement, the lateral malleolar bone was exposed. (C) Elevation of the adipofascial flap. (D) Sutures were passed into the pocket, brought out through the skin, and tied over sponge bolsters.

structed using an adipofascial turnover flap based on a peroneal artery perforator, and at 55 months after the operation, stable coverage was still maintained without recurrence of wound or ulceration at the surgical site. The recipient site also showed good contours without excessive bulkiness and did not present any difficulties in shoe fitting, and the scar at the donor site was tolerable (Fig. 3).

Discussion

Several locoregional flaps based on the distally based sural flap [1,9] have been introduced to reconstruct malleolar area defects, including the lateral retromalleolar flap [7], lateral supramalleolar flap [10], lateral calcaneal flap, and peroneal artery perforator flap [11,12]. Although distally based sural flaps have been commonly used for several decades, their complication rates have been reported to be relatively high. According to a meta-analysis, the success rate of unmodified distally based sural flap was reported to be 82% [4]. According to a systematic review of 61 papers, flap complications were recorded to occur in 26.4%, with venous insufficiency and increasing age being the independent risk factors [2]. Studies of 70 flaps in a multimorbid patient group showed a considerable necrosis rate of 36% and flap complication rate of 59% [13]. Many authors reported that the complication rate was significantly higher in old patients and those with systemic disease [13-16]. They therefore reported that refinements such as delay techniques or venous supercharging should be considered in high-risk groups [4,13,14].

In our cases, the mean age was 66.4 years old, and six out of nine patients (66.7%) were over 60 years old. Seven out of nine patients (77.8%) had one or more comorbidities, and four patients (44.4%) had two or more multiple comorbidities. However, there was not a single case of flap necrosis, and there was only one case of revision due to skin graft necrosis.

It is classically described that the peroneal perforators provide arterial supply to the distally based sural flap, and the most distal perforator is located 4 to 7 cm from the lateral malleolus. Therefore, most authors reported that the pivot point must be a minimum of approximately 5 cm proximal to the

Fig. 3. An 80-year-old male patient with a right lateral malleolar defect. (A) Preoperative photograph. (B) Elevation of the adipofascial flap. (C) Direct closure of the donor site and split-thickness skin graft of the recipient site. (D) Photograph taken 36 months postoperatively.

lateral malleolus [4,17-19]. However, some authors reported that peroneal perforators are at about 1 to 3 cm above the tip of the lateral malleolus [7,20], and using this perforator as a pedicle can lower the pivot point further and render the length of the flap shorter, thus reducing the risk of necrosis caused by a longer flap.

The authors confirmed the position of the peroneal perforator prior to surgery using a hand-held Doppler in all cases, and in one case with a possibility of vascular injury due to previous trauma, CT angiography was performed to confirm that the perforator was intact. In the authors' study, the most distal perforator among the perforators found using preoperative Doppler was determined as the pivot point, and the location ranged from 3.5 to 4.0 cm from the tip of the lateral malleolus.

Comorbidities such as old age, smoking, diabetes, and peripheral artery occlusive disease are not contraindications to surgery, but patients with peroneal artery occlusion or direct injury are absolutely contraindicated from this surgical technique [4]. Therefore, patients with previous trauma history, or with diabetes or suspected arterial occlusion may need preoperative evaluation such as Doppler or CT angiography.

Among the various methods for lower extremity reconstruction, the fasciocutaneous flap has a skin island and is therefore preferred for stable resurfacing of the defect, but the skin island must be precisely inset into the defect. Secondary debulking procedures are often necessary for patients to fit into shoes as fasciocutaneous flaps are usually large in volume [21]. The propeller flap is a local island fasciocutaneous flap based on a single dissected perforator to allow maximal arc of rotation. It can be rotated to any angle up to 180°, facilitating design and insetting [22]. However, although microanastomosis is not required, meticulous microdissection of the perforator is needed. In addition, since distally based propeller flaps are commonly used for distal lower leg reconstruction, when a skin graft is performed on a large-sized donor defect, the graft scar on the donor site located in the calf becomes more prominent, resulting in an aesthetically unpleasing result.

Adipofascial flaps for foot and ankle reconstruction have been reported by several authors [1,9,23]. Schmidt et al. [21] reported that the adipofascial flap is technically easier and faster to perform and better than the fasciocutaneous flap in aesthetic outcomes. Complication rates at the donor site were

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5.5% for the adipofascial group and 25% for the fasciocutaneous group, and the incidence of complications was significantly lower in the adipofascial flap patient group. However, it is less ideal for reconstruction of a weight-bearing surface [21,24]. In 28 cases of foot and ankle reconstruction by Mojallal et al. [9], no ulcers occurred during the follow-up period. Kim et al.'s study of 14 diabetic infected lateral malleolar bursitis cases reconstructed with this adipofascial flap also presented no recurred ulcers during follow-up [23].

According to a study of 233 burn patients, the composition of the recipient bed (whether dermis, granulation tissue, fat, or fascia) has no significant influence on the success rate of split-thickness skin grafting [25]. Nevertheless, there have been concerns about immediate skin grafting on adipofascial flaps; Li et al. [1] performed a three-stage protocol of debridement, followed by adipofascial flap coverage, and a final skin graft 1 week later. We performed those steps simultaneously because skin grafts take suitably on well-vascularized flaps, as demonstrated by Mojallal et al. [9] and Kim et al. [23].

For reconstruction of lateral malleolar defects, there are several advantages in using the adipofascial turnover flap based on the peroneal artery perforator. First, it is safe and reliable because it is a pedicled flap based on the peroneal artery perforator. Second, there is no need for microsurgical techniques, the surgical method is simple, and the operation time is short. Third, since it does not include a skin island, there are less restrictions on design and insetting, and it is less likely to leave a large and disfiguring scar in the calf area because the donor is primarily closed, not grafted. It is thin and pliable, and shoe fitting is possible without a debulking procedure. Fourth, since the dissection plane is relatively avascular, surgery can be performed without a tourniquet, and in patients with high anesthesia risk, surgery is also possible with local anesthesia.

However, the use of this technique also has some disadvantages. First, very large defects with excessive dead space can be difficult to cover when located distal to the ankle. Second, since the recipient site will require a skin graft, the grafted skin will not be as durable against friction as an island cutaneous flap. Third, it will leave a long linear scar on the calf. Therefore, it is important to explain the scar to the patient in advance.

This study has some key advantages and limitations. The use of adipofascial turnover flaps for reconstructing foot and ankle defects is not a new strategy. In this study, the number of cases was not many and the follow-up period was not too long. Nevertheless, this study included only lateral malleolus reconstruction cases using adipofascial turnover flaps. Importantly, most of the cases included (77.8%) had medical comorbidities, and our flap survival rate was 100%, which is better than other reported studies [2,4,13]. Since the dissection plane is relatively avascular, surgery can be performed without a tourniquet, which allows the procedure to be performed under local anesthesia when necessary in patients with medical comorbidities and high anesthesia risks.

Overall, we found that the peroneal artery perforator-based adipofascial flap can provide stable and reliable coverage on the lateral malleolus, involving a relatively short operation time and simple operative technique. It could be a promising option for reconstructing not only lateral malleolus but also other foot and ankle defects, especially for patients with comorbidities who are typically not indicated for more complex procedures.

Conflict of interest

No potential conflict of interest relevant to this article was reported.

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