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Perimalleolar defects: Current trends in the soft tissue management with local flap options

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Abstract
Background: Reconstruction of soft tissue defects related to the perimalleolar region is a challenging problem due to bony prominences and lack of local soft tissue. Treatment options are limited in reconstruction of this region. Local flap covers are safe alternatives to free flaps in patients with lower extremity injuries and they provide fast and simple options for managing difficult to reconstruct wounds.
Methods: We conducted a retrospective analysis of 23 post-traumatic patients using a regional flap cover. We used different flap options for the patients based on availability of the perforators and soft tissue for cover of defects and surgeons preference for the flap cover. We included all patients with post-traumatic defects in perimalleolar regions for which loco-reional flaps were available. We excluded patients with large defects for which free flaps were needed or local flap options were not available.
Results: Our series includes 23 post-traumatic perimalleolar defects, for 20 defects we performed perforator based pedicled fasciocutaneous flap cover and 3 defects were covered with pedicled muscle flap with skin-grafting. Uneventful primary healing was recorded in 21 patients. A complication occurred in our 2 patients; in one patient there was partial skin graft loss and in another patient there was partial flap necrosis of propeller flap, due to venous insufficiency, that required secondary skin grafting.
Conclusions: Choice of the local flap cover for perimalleolar defects should be based on size and location of the flap, limitations related to available flap options and surgeons preference of flap cover.

Keywords: Perimalleolar defects, reverse sural flap, posterior tibial artery perforator based flap, propeller flap, peroneus brevis muscle flap

Introduction
High-energy traumas in lower extremities are common and ankle fractures are among the most common orthopedic surgical procedures [1]. Reconstruction of soft tissue defects related to the complications of ankle fracture surgery is a challenging problem due to bone prominences and lack of local soft tissue [2]. Treatment options are limited in reconstruction of this region. Free flap transfers have become the first choice in the reconstruction of wide soft tissue defects involving distal lower extremity. However, free flap transfer is a highly complex surgical procedure, and it is not ideal especially for patients with high rates of comorbidities due to long operative times [3],
Consequently, in recent years, local flap covers have become safe alternatives in patients with lower extremity injuries and they provide fast and simple options for managing difficult to reconstruct wounds, but there are a limited number of studies using perforator flaps in reconstruction of the postoperative complications of lower extremity trauma surgeries in the literature [4].
In our study, we report our experience with reconstruction of soft tissue defects of medial and lateral malleolar regions using various flap cover options for postoperative complications of ankle fracture-related surgeries. We used flap cover such as peroneus brevis muscle flap cover, posterior tibial artery perforator based flap cover, sural artery perforator based flap(neuro-fasciocutaneous flap) cover and perforator based propeller flap cover, lateral supramalleolar fasciocutaneous flap.

Patients and methods

We conducted a retrospective analysis of 20 post traumatic patients, who underwent reconstruction for either or both medial and lateral malleolar defect, between march 2019 to march 2021, using a regional flap cover. We used different flap options for the patients based on availability of the perforators and soft tissue for cover of defects and surgeons preference for the flap cover.

The vascular status of the involved lower limb was assessed clinically by palpation of the posterior tibial and dorsalis pedis pulsation, and confirmed by Doppler flow meter. Further radiological investigation, i.e. ct angiography was performed when needed. All patients underwent a preoperative Doppler examination to identify the nutrient artery for the flap cover. In all patients we recorded patients characteristics, i.e age, sex, size and location of the defect, post operative complications, time to heal and secondary revision surgery.

We included all patients with post traumatic defects in peri malleolar regions for which loco-reional flaps were available. We excluded patients who had large defects for which free flaps were needed or local flap options were not available.

Results

Our series of 23 post traumatic patients includes 19 males and 4 females, aged between 12 to 66 years, with a follow up ranging from 2 to 10 months. In our study most of the patients had no comorbidity, except a single patient who was known and controlled diabetic.

Out of 23 defects, 9 were over lateral malleolus, 4 over achilles and 11 defects found over medial malleolus. 20 defects were performed with perforator based pedicled fasciocutaneous flap cover and 3 defects were covered with pedicled muscle flap with skin grafting. More specifically, reverse sural artery based perforator based fasciocutaneous flap was used for 7 defects, peroneus brevis pedicled muscle flap with skin grafting was used for 3 defects, posterior tibial artery perforator based pedicled flap was used for 4 defect cover, lateral supra-malleolar artery perforators based flap was used for 3 defects and perforator based propeller flap cover was used for 6 defect cover. In one of our reverse sural flaps, flap cover was performed in a delayed manner and transferred to the wound at a second stage, one week after the primary procedure. The detailed information regarding the site of defect and choice of flap cover is given in the table below.

Uneventful primary healing was recorded in 21 out of 23 flap covers. A complication occurred in our 2 patients ; in one patient there was partial skin graft loss and in another patient there was partial flap necrosis of propeller flap, due to venous insufficiency, that required secondary skin grafting.

We performed skin grafting for the donor area of flap in most of the patients.

Table 1 Details of patients, characteristics of defect and used flap and its complications

Patient No.	Ag E	Gender	Defect Region	Defect Size (Cm)	Flap	Complicat Ions
1	22	Male	Lateral malleolus	4*3 cm^2	peroneus brevis muscle flap with skin grafting	No
2	24	Male	Lateral malleolus	5*4cm^2	peroneus brevis muscle flap with skin grafting	No
3	28	Male	Lateral malleolus	7*3 cm^2	lateral supra malleolar flap	No
4	34	Female	Lateral malleolus	11*4cm^2	reverse sural neurocutaneous flap	No
5	12	Male	Lateral malleolus	6*3cm^2	lateral supra malleolar flap	No
6	40	Male	Lateral malleolus	12*7cm^2	reverse sural neurocutaneous flap	skin graft loss over flap donor site
7	41	female	Lateral malleolus	5*2cm^2	peroneus brevis muscle flap with skin grafting	No
8	32	Male	Lateral malleolus	9*6cm^2	propeller flap	No
9	26	Male	Lateral malleolus	9*3cm^2	lateral supra malleolar flap	No
10	51	female	Achilles	5*4cm^2	propeller flap	No
11	45	Male	Achilles	6*4cm^2	reverse sural neurocutaneous flap	No
12	16	Male	Achilles	3*3cm^2	propeller flap	No
13	55	Male	Achilles	8*4cm^2	reverse sural neurocutaneous flap	No
14	34	Male	Medial malleolus	6*5cm^2	reverse sural neurocutaneous flap	No
15	25	female	Medial malleolus	7*4cm^2	posterior tibial artery perforator based flap	No
16	66	Male	Medial malleolus	5*3cm^2	propeller flap	No
17	49	Male	Medial malleolus	5*4cm^2	propeller flap	No
18	22	Male	Medial malleolus	8*5cm^2	reverse sural neurocutaneous flap	No
19	21	Male	Medial malleolus	6*4cm^2	reverse sural neurocutaneous flap	No
20	20	Male	Medial malleolus	4*3cm^2	posterior tibial artery perforator based flap	No
21	34	Male	Medial malleolus	9*6cm^2	posterior tibial artery perforator based flap	No
22	36	Male	Medial malleolus	11*7cm^2	posterior tibial artery perforator based flap	No
23	40	Male	Medial malleolus	8*5cm^2	propeller flap	partial flap necrosis

Discussion

Soft tissue reconstruction in the lower extremity remains a difficult problem for which a multitude of surgical strategies have been described ranging from direct wound closure, skin grafting, loco regional flap cover to microsurgical free flap procedures. For complex wounds, selection of the right technique should be based on the safer flap according to the vascularity of the limb and the patient's comorbidities [6].

An evolution of treatment strategies began in the 1970 and 1980s with the development of microsurgical techniques which brought a tremendous improvement in the treatment of lower extremity soft tissue defects beginning with the use of muscle free flaps then incorporating fasciocutaneous flaps, which appear to be reliable with good functional and cosmetic results and lower donor site morbidity [20, 21]. For complex wounds, selection of the right technique should be based on the safer flap according to the vascularity of the

limb and the patient's comorbidities [6] Free flaps remain an essential tool in this area for large or composite defects. Free tissue transfer has been extensively used during the recent years, mainly for large and/or more complicated tissue defects; despite the high success rates of free flaps even in diabetic patients, careful case selection and pronounced microsurgical skills are required for performing those demanding procedures [5].

Since the 1990s, an enhanced knowledge of vascular anatomy has led to the increase of use of perforator flaps 35, 36 and this trend has gained more importance since the introduction of pedicled-perforator flaps. This technique has also gained popularity, as surgical techniques and experience developed from the microsurgical experience have improved the dissection. Their application for the reconstruction of the lower leg presents many advantages: a simpler technical procedure which does not require microsurgery, preservation of the source artery and underlying tissue, minimal donor-site morbidity, and reconstruction using "like-by-like" principles with good cosmetic and functional results [26].

Among loco-regional flaps, the distally based neurocutaneous flaps have been successfully used for soft tissue reconstruction of traumatic malleolar defects during the last two decades [7-9]. Salmon first reported that the superficial nerves of the leg (sural, saphenous and superficial peroneal nerves) are accompanied by arterial axes delivering multiple vascular branches to the overlying skin and anastomotic vessels to the suprafascial and deep vascular networks of the leg. In 1992, Masquelet *et al*. based on their anatomical studies, confirmed these observations and pointed out similar characteristics in the vascular supply of these "neurocutaneous" skin island flaps, namely the sural artery and the lateral supramalleolar flap, both supplied by vascular axes of sensitive superficial nerves [10]. Advantages of these distally based cutaneous flaps include the avoidance of microsurgical procedures and the preservation of major arterial axes of the extremities, the latter being extremely important in lower limbs with insufficient blood circulation [10]. Indications of those flaps in reconstructing foot and ankle wounds are quite similar, with the lateral supramalleolar flap being mostly indicated for covering the medial malleolar area, the Achilles zone and the distal areas of the foot [8, 11]; the reverse sural flap is more frequently used for covering the posterior and weight-bearing heel and the lateral malleolar areas (fig. 1) [7, 12]. Delaying the transfer of neurocutaneous flaps has also been reported in order to improve the chances of flap transfer success. Delay phenomenon is well known to increase functional blood flow to the flap and, therefore, to enhance the survival of critically vascularized skin islands. In our series, one patient who presented a composite tissue loss over the distal lateral side of the foot with malleolar defect, was treated with a delayed lateral supramalleolar flap that successfully reconstructed the defect in a two-staged procedure.

Fig 1: Lateral malleolar defect covered with reverse sural neurocutaneous flap

One of the major disadvantages of using the reverse neurocutaneous flaps comparing to the propeller perforator flaps and muscle flap, is the donor site morbidity including sensory disturbances over the lateral aspect of the foot and unpleasant scarring over the flap's donor site which is usually skin grafted. Healing of the donor site was problematic in one of neurocutaneous flap case of our series, due to "no take" of primary skin grafts, resulting in even poorer cosmetic outcome.

Parallel advanced studies on the vascular anatomy of the lower leg, resulted in the description and harvesting of new pedicled skin island flaps supplied by perforator vessels, emerging from the major arterial axes of the leg, i.e. the anterior and posterior tibial, and the peroneal arteries [13]. Even in diabetic patients with compromised circulation, a major vascular axis -most commonly the peroneal artery- remains patent with viable perforators to supply a perforator flap [14]. Georgescu *et al*. published a series of 25 diabetic lower limb wounds that were successfully reconstructed with propeller-type skin flaps mainly based on perforators of the peroneal and posterior tibial artery [15].

The posterior tibial artery is the direct continuation of the popliteal artery. Usually, it is the dominant vessel of the trifurcation. The posterior tibial artery is accompanied by two venae comitantes and through its course in the leg supplies two to four perforators, each accompanied by two venae comitantes (venous perforators from the greater saphe-nous vein), predominantly septocutaneous, arising from with-in two intermuscular septa: one between the soleus and the flexor digitorum longus muscle and the other between the flexor digitorum longus muscle or tendon and the medial aspect of the tibia [26, 27]. The most recent study to evaluate the anatomic location of most distal perforators of the posterior tibial artery was con-ducted by Bulla *et al*. [28] to provide an anatomic rationale for safe elevation of distally based medial adipofascial flaps of the leg, they found adistal perforator in all specimens with a mean caliber of .77 mm passing through a septum between the flexor

hallucis longus muscle and flexor digitorum longus muscle, the lowest perforator lying at a median distance of 6.75 cm (ranging from3.5 to 8.2 cm). The veins accompanying these arteries show anatomic variations (two, one, or even none of the veins accompanying the artery). This is very important to the initial survival of this flap [29]. The posterior tibial artery perforators are connected in anaxial network. This anatomy allows the surgeon to raise large designed flaps that can in-set into defects of different sizes and shapes.(fig-2) [30].

Fig 2: Medial malleolar defect covered with posterior tibial artery perforator based faciocutaneous flap cover

With the anatomical knowledge of the vascular territory of the lateral supramalleolar artery, we know the flap has a well-defined territory and a reliable vascular axis. The donor site has a well-vascularized muscular bed and is reliably covered with a split-thickness skin graft. The skin of the lateral aspect of the leg is supplied by terminal branches arising from the perforating branch of the posterior peroneal artery. It has been demonstrated by Masquelet *et al*., that this perforating branch is constant, almost always emerges 5 cm above the lateral malleolus in the groove between the tibia and the fibula, and gives two or three ascending cutaneous branches [24]. These branches perforate the fascia and continue as a vascular network in the lateral aspect of the leg. Therefore, the skin territory of the flap should not go above the middle third or extend beyond the tibial crest medially and the posterior border of the fibula laterally. Also, the origin of the perforating branch of the posterior peroneal artery acts as the point of rotation. It can be raised as an Island flap or a transposition flap.(fig-3) Due to the large skin paddle and a wide rotation arc, this flap is able to be employed to cover defects of the ankle and foot. However, for these, it is a safer option to deploy the lateral supramalleolar flap as a fasciocutaneous transposition flap. This is because the pedicle with the island flap is easily prone to kinking when the flap is swung to cover ankle and foot defects making such flaps prone to necrosis. This requires a staged procedure requiring more than one operative procedure. The lateral supramalleolar flap is a reliable option in the resurfacing and covering of various skin defects in the lower extremity. It is particularly useful to cover the middle to lower third leg, ankle, and foot defects. It can also be used as a cross-leg flap for contralateral defects [25].

Fig 3: Lateral malleolar defect covered with lateral supra-malleolar artery perforator based faciocutaneous flap cover

The introduction of the propeller flaps expanded the reconstructive options for lower limb soft tissue. They increase the potential donor sites, including those anatomical districts where conventional pedicled flaps were not available. Actually, a propeller flap may be raised anywhere a sizable perforator is present (fig-4). Moreover, the color and texture of the skin in the proximity of the defect match the recipient area. Also, the donor site morbidity is minimal since no major vessels are sacrificed, and the donor area may be closed primarily in the most part of cases. Operative technique has been gradually refined over the last few years so nowadays propeller flaps are considered to be an effective procedure for reconstruction, in almost all the anatomical districts, of small/medium size defects [24]. Propeller flaps are a good alternative, specially in the Achilles tendon region and the ankle. The poor quality of the skin near the defect and the presence of edema are the main contraindications for propeller flaps, which should not be attempted in those circumstances. Though propeller flaps have less donor-site morbidity as compared to a pedicle flap, they, however, have certain dis-advantages, including the requirement of microsurgical dis-section, which need more expertise and have a higher complication rate as compared to a pedicled flap used in our series where a remarkably low complication was observed.

Fig 4: Medial malleolar defect covered with perforator based propeller flap cover

Use of the proximally based peroneus brevis as a pedicled muscle flap was first described by Pers and Medgyesi in 1973 [16]. In 2001, Eren *et al*. described the use of the distally based peroneus brevis flap for reconstruction around the ankle [17]. However, the main contribution to the literature on this flap has been the 109 cases reported in 2010 by Schmidt and Giessler [18]. Other smaller series have also been reported [16]. This muscle flap is easily raised, whether pedicled proximally or distally.

As a proximally based flap, the peroneus brevis is useful for cover of small defects of the distal third of the tibia down to the ankle; particularly the perforators supplying the distally based peroneus brevis flap on the lateral aspect of the leg adjacent to the ankle are constant and probably because they are deeper, seem to escape damage in most injuries of the ankle.(fig-5) The distally based flap can be raised with a segment of the vascularised fibula if needed. It is particularly a good choice for defects of the lateral malleolus and tendo achilles, even in older patients.

Fig 5: Lateral malleolar defect covered with pedicled peroneus brevis muscle flap with skin grafting

Whether used for defects of the leg or ankle, the muscle, initially bulky, has the benefit of 'auto thinning' with time. As the muscle atrophies, it provides a better aesthetic result than local fasciocutaneous flaps, although the overlying skin graft is rarely ideal in respect of colour, contour and irregularity of surface. This has particular value around the ankle as the reconstruction is less likely to interfere with footwear. Several studies have shown that the loss of the peroneus brevis, with the peroneus longus still functional, does not cause instability of the ankle [19].

With our short experience so far, the distally based peroneus brevis muscle flap could be the flap of choice for defects over the lateral malleolus, but is not worth trying for defects on the medial malleolus particularly when the defects are on the posterior aspect of the medial ankle.

Reconstruction of the soft tissue defects related to the perimalleolar region is a challenging problem due to bony prominence. Though there are many loco regional flap options available for reconstruction. With consideration of all above parameters, choice of flap cover should be based on location of the defect, size of the defects, availability of the perforators, limitation of available flap option and surgeons preference.

Limitations of the study

This study has potential limitations. The location and the size of the defect has played an important role in selecting the appropriate flap; therefore, a selection bias may have influenced our study. This could not have been avoided, since it is generally accepted that neurocutaneous flaps can cover more extended defects, especially when located in more distal areas of the foot.

The most important limitation of our study is the small size of the sample, indeed it is possible that an association between risk factors and complications (including flap failures) might have been missed due to insufficient sample size. However, the other variables considered (age, gender, etiology of loss of substance, comorbidities and type of complications) are homogenous.

Conclusion

There are many locoregional flap options available for the peri malleolar region soft tissue defects. Choice of the flap cover should be based on size and location of the flap, limitation related to available flap options and surgeons preference of flap cover.

Conflicts of interest: None

Informed consent: informed consent was obtained from all patients included in the study where ever applicable. Written informed consent has been obtained from all individual for use of there clinical photographs in this study.

Ethical approval: all procedures performed in studies involving human participants were in accordance with

ethical standards of the institutional and or national research committee and with the 1964 helsinki declaration and its letter amendments or comparable ethical standards

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