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Application of Subunit Principle in Foot Reconstruction

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ABSTRACT

Background: Foot is a vital structure to support standing and walking. Any soft tissue defects in the foot will impede the normal activities of patients. The skin and soft tissue underneath are different in various parts of a foot. The plantar skin is glabrous and thick with solid anchorage to the deep structure. Therefore, the reconstruction aim is to restore the stability of the foot skin to adapt to the weight-bearing and to resist shearing force. In addition, a good sensibility should be taken into account for the reconstruction. The skin in the foot dorsum is thin and pliable, while the ankle region has great tension during movement and a good stability is required for shoes-wearing **[1]**.

Aim of the Study: Mapping of the foot into different subunits to help us in selection of the most suitable method of foot reconstruction with least morbidity of the recipient and the donor site and the best possible way of rehabilitation.

Patients and Methods: 25 patients with foot soft tissue defect were treated in Plastic surgery department, Menoufiya University. Based on the location and extension of the soft tissue defects, we used 11 local fasciocutaneous or free flaps for foot reconstruction using the subunit repair principle.

Conclusion: Considering foot structural differences, the subunit repair principle could assist us in choosing the proper flaps in the reconstruction of the foot.

INTRODUCTION

The role of the foot in walking and weight-bearing and in the normal appearance of the foot places exceptional demands on the techniques used for its reconstruction. The goal of reconstruction is to provide sensate and stable coverage for the foot soft tissue defect with minimal donor site morbidity **[2]**.

Flap choices for soft tissue reconstruction after tumor ablation are mainly dependent on what is available, what is needed or on the experience of the reconstructive surgeon. Langstein, reported that free flaps facilitate limb salvage and preserve meaningful limb function in patients who undergo resection of soft tissue malignancies of the foot. It is possible that the choice of flap is quite different between defects from tumor excision and from traumatic defects. This is because in the event that there would be a local recurrence, reverse pedicled flaps would have increased the contamination of the extremity **[3]**.

Foot wounds with exposure of tendon or bone usually result from trauma, resection of malignant skin tumors, burn injury, or neurotrophic ulceration.

Reconstruction of this particular region presents a great challenge due to the limited local soft tissue availability and weight-bearing requirement. Until now, a great number of reconstructive alternatives have been described in the literature, including cross-leg flaps, local fasciocutaneous flap or free flaps **[4]**. However; it is not clear how to choose the appropriate flaps for the different parts of the foot **[5]**.

Parameters used for the evaluation of the reconstructive procedure:

1- Pain: Required information (doses of medication for pain relief).

2- Function: Required information (restriction in activities and the degree of occupational disability).

3- External support to compensate for instability during standing or walking: Required information (Type of support and the frequency of its use).

4- Walking ability: Required information (Walking distance and limitations in its type (Inside/ outside, uphill, stairs, etc.).

5- Gait: Required information (Type of gait abnormality and resultant restrictions or deformity).

6- Emotional acceptance: Required information (Patients' emotional reaction to the functional result) **[6]**.

Recent studies on the plantar pressure distribution with a baropodometry help in Baropodometric localization of the defect into (WB or non weight

bearing NWB) areas (Fig. 1) and this help in selection of the proper methods for reconstruction by identifying functional bone loss and help in planning the repair of the arches [7].

Aim of the study:

Mapping of the foot into different subunits to help us the selection of the most suitable method of foot reconstruction with the least morbidity of the recipient and the donor site and the best possible way of rehabilitation.

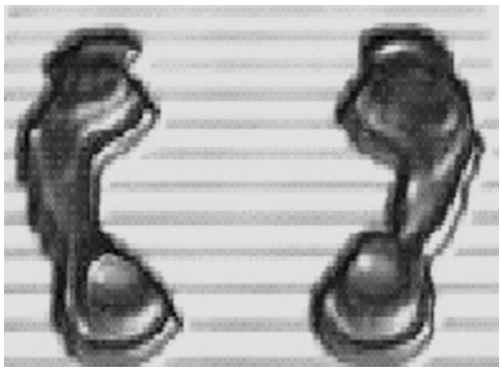

Fig. (1): Computerized Baropodometry of the foot.

PATIENTS AND METHODS

Between August 2005 and May 2009, 25 patients were treated in Plastic surgery Department, Menoufiya University. There were 20 males and 5 females, ranging in age from 6 to 83 years, with a mean age of 56 years. The preexisting conditions necessitating subsequent reconstruction: Resection of skin tumor in 2 patients (one case of hemangioma and the other of malignant fibrosarcoma), post-traumatic soft tissue defects in 11 patients, burn injury in 2 patients and Diabetic neurotrophic ulceration in 10 patients. The size of soft tissue defects varied from 2x2cm to 9x8.5cm.

Preoperative preparation:

1- Plain foot X-ray: Mainly for patients with trauma.
2- MRI: To evaluate soft tissue damage, most important mainly in cases of heel reconstruction.
3- Doppler ultrasonography: To assess vascular pattern of the foot.

Evaluation of foot defect considered:

- Amount of tissue loss (dimension & extension of the defect).
- Localization (WB or NWB areas).
- Neurovascular damage.

Allen's test: Is essential in cases planed for free radial forearm flap.

Based on the location and the extension of the soft tissue defects, we used 11 local fasciocutaneous or free flaps for reconstruction, using the subunit repair principle.

Subunits of foot and application of flaps:

According to anatomic structure, function and reconstruction requirements, the foot can be divided into six subunits: Plantar forefoot and dorsal forefoot regions, plantar hind foot, dorsal hind foot regions, midfoot region and ankle region. A complete degloving of plantar or dorsal foot soft tissue was not seen. The soft tissue defects presented in different subunits and the subsequent flap applications are summarized in (Table 1).

Reconstructive options for different subunits of the foot:

General repair principle:

In the case of a malignant skin carcinoma in the foot region, a wide local excision was performed and the intraoperative biopsy showed the clear margin of the wound. Then the wounds were covered primarily by a flap.

If soft tissue defects in the foot were caused by trauma, burn or neurotrophic denervation, a complete debridement was first performed, including removal of the necrotic tissue and granulation tissues as well as the unstable scar around the wounds, then an antibiotic therapy ensued. After the local wound bacterial culture confirmed that there was no infection, a secondary flap transfer was performed for the wound coverage.

When transposing a flap as a reverse-flow flap, a teardrop skin paddle was usually designed over the flap pedicle. After flap elevation, an incision was made between the flap donor site and the defect site. An open tunnel was then prepared and the teardrop skin paddle left on the pedicle was used to cover the tunnel.

Reconstruction of the plantar forefoot region:

When the wound was located in the plantar forefoot region, a V-Y advancement flap was used.

Reconstruction of the dorsal forefoot region:

For the dorsal forefoot wound, Local adipofascial Dorsalis pedis artery flap was rotated for the wound coverage (Inferior based) (Fig. 2).

Compared with other flaps, this adipofascial flap has the following advantages:

- Thinner and produced less bulkiness to the recipient site.

• Minor aesthetic Sequelae to the donor site.
• No need for 2nd stage for division of the pedicle.

Reconstruction of dorsal hind foot region:

The posterior dorsum wounds were covered by a sural neurofasciocutaneous flap (Fig. 3), a line was marked from a point halfway between the Achilles tendon and the lateral malleolus at the ankle extending to the midline between the two heads of the gastrocnemius muscle.

The flap was raised under the deep fascia with a pedicle as wide as 3cm to include the sural nerve and the lesser saphenous vein. The flap was rotated based on the pivotal point to cover the dorsal hind foot region. The donor site could be closed directly when the width of the flap was less than 4cm. The pedicle region could be closed primarily by suture of the skin paddle to the tunnel skin.

Reconstruction of the plantar hind foot region:

The plantar hind foot wounds were usually covered by a medial plantar flap. After the confirmation of patency of the dorsalis pedis and posterior tibial arteries, the flaps were designed in the instep region according to the size of the defects.

In the lateral heel region, a calcaneal flap was applied: The flap was dissected from distal to proximal in a supraperiosteal plane. The lateral calcaneal artery and the lesser saphenous vein as well as the sural nerve should be incorporated within the flap. After flap elevation, the flap was transferred to the recipient area with a skin paddle over the pedicle and the donor site was covered with a split thickness skin graft.

Sural neurocutaneous flaps were also used in the coverage of this region.

Radial forearm free flap also used for reconstruction of planter hind foot region, revascularized side to end on the posterior tibial artery and vein (Fig. 4).

Reconstruction of ankle region:

This region can be sub divided into three regions: The lateral malleolus region, the medial malleolus region and the Achilles tendon region.

** Lateral malleolus region:*

• Free radial forearm flap: (Radial vessels were anastomosed to the Dorsalis pedis vessels.
• Dorsalis pedis flap (superior based) (Fig. 5).
• Lateral supramalleolar flap.

** Medial malleolus region:*

• Medial supramalleolar flap: Supplied by posterior tibial artery perforators.
• Lateral supramalleolar flap: This was based on perforators from the peroneal artery.

Used when the defect was located in the proximal part of the medial malleolus region.

** Ankle Achilles tendon region:*

• Sural fasciocutaneous flap.
• Regional rotation flaps (Dorsalis pedis) (Fig. 6).

Midfoot coverage:

Defects on the Midfoot are non-weight bearing and are were treated with a skin graft.

Postoperative care:

• Both legs are slightly elevated.
• Patients are generally not allowed to bear weight on the operated foot for 6 weeks if the plantar surface is involved by the use of appropriate off loading devices.
• For dorsal reconstruction, patients are allowed to ambulate early.
• Monitor the viability of the flap in the early postoperative period.
• For free flaps, monitor the flap with the aid of a Doppler probe to check the patency of the microanastomosis.
• Use of appropriate silicon footwear in planter (WBAs) till the return of protective deep pressure sensations.

Table (1): The subunits of the foot and flaps used for coverage.

Subunits	Cases	Flaps (No.)
Plantar forefoot	2	V-Y advancement flap
Dorsal forefoot	3	Local DPF (2), FRFF (1)
Plantar hind foot (weight bearing region)	7	MPF (4), LCF (1), DPF (2)
Plantar hind foot (non weight bearing)	3	SNCF (3)
Dorsal hind foot	2	SNCF (2)
Ankle (medial malleolus)	2	MSMF (1), LSMF (1)
Ankle (lateral malleolus)	3	DPF (1), Free RFF (1), LSMF (1)
Ankle (Achilles tendon)	3	Local RT (2), SNCF (1)

DPF : Dorsalis pedis flap. SNCF : Sural neurocutaneous flap.
FRFF: Free radial forearm flap. MSMF: Medial supramalleolar flap.
MPF : Medial plantar flap. LSMF : Lateral supramalleolus flap.
LCF : Lateral calcaneal flap. RT : Rotational flap.

Fig. (2): Reconstruction of the Dorsal Forefoot by Inferior based adipofascial DPF.

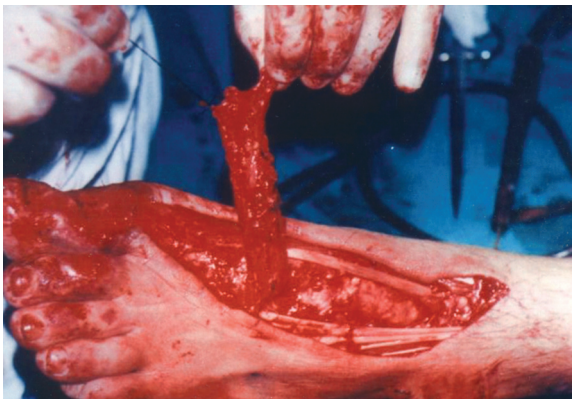

Fig. (2-A): Soft tissue defect on dorsal forefoot & elevation of adipofascial DPF.

Fig. (2-B): Grafting after inset of the flap.

Fig. (3): Reconstruction of Dorsal Hind foot Region by Reversed SNCF.

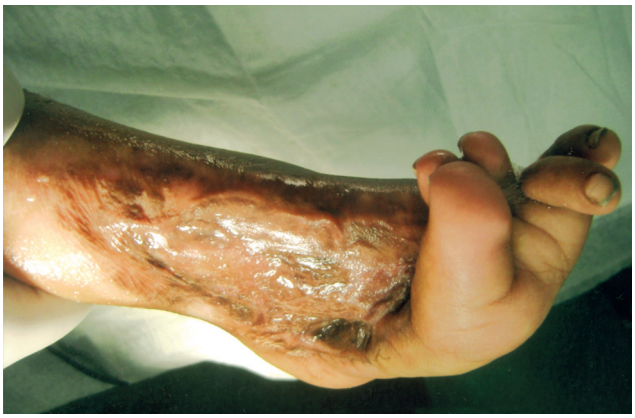

Fig. (3-A): Postburn contracture of dorsal hind foot.

Fig. (3-B): Late postoperative.

Fig. (4): Free Radial forearm free flap for reconstruction of Planter hind foot region.

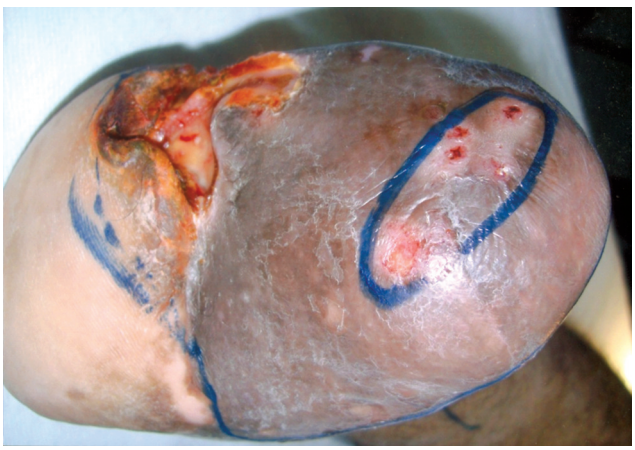

Fig. (4-A): Plantar hind foot unstable ulcer.

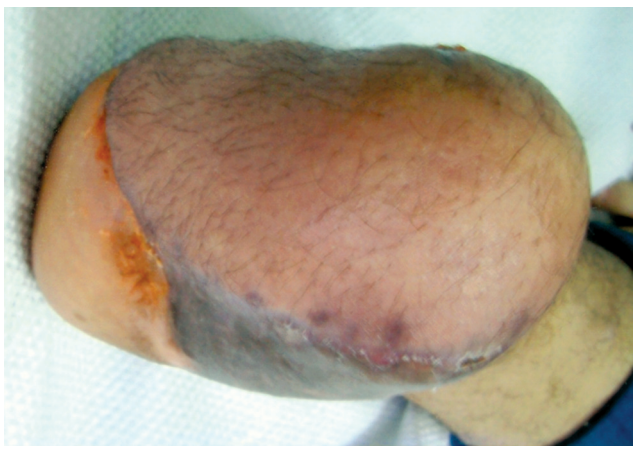

Fig. (4-B): Late postoperative.

Fig. (5): Dorsalis pedis flap (superior based) for reconstruction of lateral malleolus.

Fig. (5-A): Lareal malleolus defect.

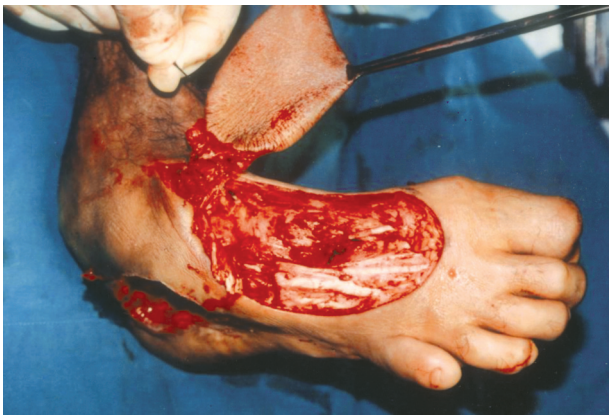

Fig. (5-B): Elevation of DPF.

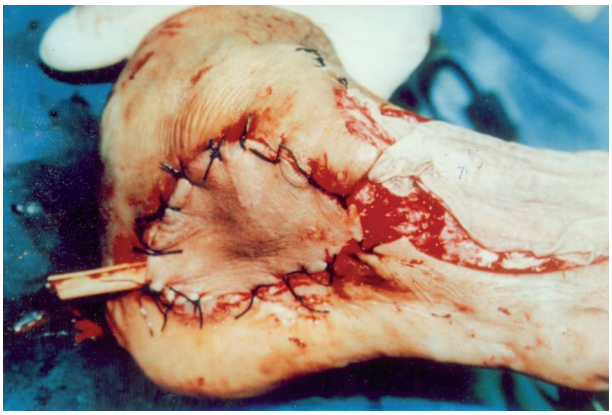

Fig. (5-C): Inset of the flap in the defect.

Fig. (6): (Dorsalis pedis rotation flap) for reconstruction of tendoachilles region.

Fig. (6-A): Margolin ulcer in tendoachilles region.

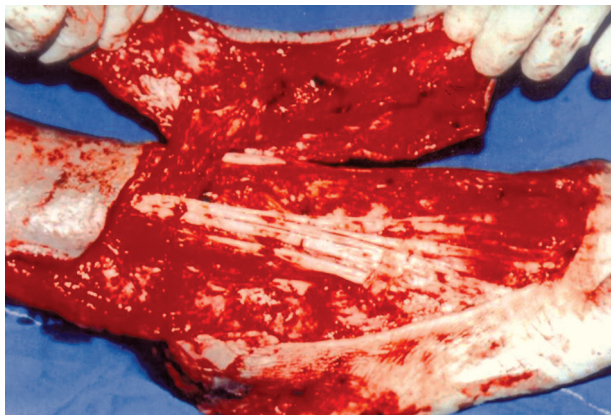

Fig. (6-B): Elevation of DPF.

Fig. (6-C): Late postoperative.

RESULTS

All cases were followed-up from 3 months to 67 months, with an average of 30 months. Two cases with regional rotation flaps for the Achilles tendons coverage underwent marginal flap necrosis and healed by local wound care. One patient ambulated 2 weeks after the sural neurofasciocutaneous flap transfer was used to cover the heel region; the wound dehiscence and partial superficial skin necrosis occurred between the flap and donor site. It was healed by wound dressing changes. All the other flaps survived uneventfully. However, the free forearm flap was bulky in the lateral malleolus region. It had to be debunked half a year after the first operation. It was demonstrated that all flaps

had normal or protective sensitivity without any skin breakdown. All patients ambulated well and could wear normal shoes.

DISCUSSION

The skin in the foot dorsum is thin and pliable, while the ankle region has great tension during movement and a good stability is required for shoe-wearing. Considering these structural differences, we thought that the subunit repair principle could assist us in choosing proper flaps in the reconstruction of the foot [1].

In the case of small soft tissue defects in the planter forefoot, V-Y advancement flap based on the plantar circulation were used. Recently, it was reported that the medial plantar flap could be transferred as a distally based pedicled island flap [8]. The small to moderate size wound located in the plantar forefoot could be repaired with this glabrous skin flap [9]. The precondition of this procedure was that the dorsalis pedis artery and the posterior tibial artery should be patent. In the lateral or medial site of the forefoot, a local dorsal pedis flap could be rotated to cover small or moderate-sized wounds satisfactorily [10].

According to our own experience, a distally based fasciocutaneous flap could not cover the forefoot reliably. A free flap had to be used to repair this region when there was an extensive soft tissue defect. The confirmation of the patency of the posterior tibial artery was necessary prior to the operation [11].

The plantar hind foot, especially the weight bearing region, requires thick, sensorial, durable and glabrous skin. The medial plantar artery flap raised from the non weight bearing instep of the plantar foot is a sensate flap. The skin texture is similar to that of the weight bearing region [12]. Therefore, it was an ideal approach to resurfacing the plantar hind foot region. However, the flap offers limited soft tissue for coverage of an extensive soft tissue defects in the lateral heel. The lateral calcaneal artery flap has provided a good alternative to this defect [13]. We used the medial plantar flap combined with a lateral calcaneal artery flap in this situation. Both flaps had good sensibility and provided durable skin and soft tissue; no recurrent ulceration was observed postoperatively. When the soft tissue coverage was located in the instep region, a distally based sural neurocutaneous flap was transferred and fit this region well. For the soft tissue defect located in the dorsal hind foot, the distally based sural neurocutaneous flap was a good reconstructive option.

In previous series, a distally based posterior tibial artery flap was used. The flap was very reliable and provided enough soft tissues for wound coverage [14]. However, the sacrifice of a main artery of the foot may worsen the injured foot. Thus, the flap should not be the first choice for reconstruction [15].

In the ankle region, local rotational flaps were attempted for the wound coverage in two cases. The partial flap loss resulted in delayed wound healing due to the tight tension of the local tissue. So, it seemed that a local rotation flap was not appropriate for reconstruction of this region. The lateral calcaneal flap and medial or lateral supramalleolar flap were good alternatives for wound coverage in the lateral or medial malleolus region [16]. They had the common advantage of not sacrificing the main blood vessels of the foot. However, they were only suitable for coverage of small to moderate size wounds as they do not provide sufficient skin and soft tissue [17]. For the coverage of extensive soft tissue defects, we used a free radial forearm flap. The disadvantage was that the flap was very bulky and made shoe-wearing difficult. Alternatively, when the main perforator is not jeopardized by the trauma, the distally based sural neurocutaneous flap is suitable for reconstruction of extensive soft tissue defects in this region.

The main complication of reverse flow flaps was venous congestion. In our series, we did not see this complication. We thought the following points might play a vital role in the raising of a reverse flow flap for reconstruction of foot soft tissue defects: Firstly, the pivotal point of the flap should be detected before the operation using Doppler ultrasound or angiography. The distance from the pivotal point to the closest edge of the skin defect was measured. A 1- to 2-cm length should be added to the pedicle length for the rotation of the pedicle. The design of flaps was 1cm larger than the original size of the defects to facilitate the final closure of the wounds. Secondarily, the flaps were elevated under the deep fascia plane and superficially in the sub dermal plane to protect the pedicle. The subcutaneous pedicle should be as wide as 3cm to improve the venous return. Finally, a wide tunnel was made between the pivotal point and the recipient site. A teardrop skin paddle was left over the pedicle to facilitate the closure of the tunnel. Drainage was necessary to prevent the postoperative hematoma under the flaps. All these measures contributed to a wound closure without tension and allowed good perfusion of flaps. However, the reverse flow flaps were primarily non-sensory flaps and could not resist the

shearing force during standing and walking in an early postoperative period **[18]**. Otherwise, a persistent ulceration likely occurred at the junction between the flap and the local skin. Therefore, it was suggested that patients wear protective shoes and avoid weight-bearing prior to normal ambulation.

Conclusion: Considering foot structural differences, the subunit principle could assist us in choosing the proper flaps in foot reconstruction.

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