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Role of Flaps and Skin Grafts in the Management of Neuropathic Plantar Ulcers

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INTRODUCTION

When I for the first time saw leprosy patients at ALERT Hospital, Addis Ababa in 1986, I was taken by surprise seeing so many people walking around on seriously neurologically impaired feet. Most of them were relatively young people who had to walk a lot in order to earn their daily living. Foot ulcers were very common. As a plastic surgeon, I was familiar with covering tissue defects of different kinds with skin grafts and flaps. I must say I started off rather enthusiastically trying to cover many plantar ulcers, believing that time could be saved and that the quality of life could be improved for many patients by an active surgical approach to the ulcer problem. When I look back today, the only group of patients I feel really benefited from modern plastic surgical procedures, and actually got a "new foot", was a rather small but still important group of patients with big heel defects, ulcers as well as unstable scars. The medial plantar island flap turned out to be very successful and represented a real improvement compared with surgical procedures described in more traditional textbooks for surgeons dealing with leprosy related problems. Otherwise, it is also my experience that one often can be quite conservative waiting for secondary healing of the majority of plantar ulcers in leprosy. Of course, the basic principles of pressure point reduction and adjustment of footwear must be addressed. But there are exceptions, and covering procedures sometimes have to be considered.

GENERAL CONSIDERATIONS

The skin and underlying soft tissue of the sole of the foot is anatomically unique and damage to the weight bearing portions requires reconstruction by similar tissue for the best long-term results. There seems to be an innate mechanical property of the sole itself that gives it capacity to bear weight and to withstand shear, which is very important in preventing ulceration, as is sensation.[6,7] The firm adhesion of skin to plantar fascia limits skin mobility and makes it a firm-gripping pad for heavy traction. Therefore, local flaps are employed whenever possible. As a main principle, tissue from a non-weight bearing area of the foot is moved into a weight bearing area and the donor site may or may not have to be covered with a skin graft.

Before considering any surgical procedure to introduce new tissue in an ulcerated plantar area, the cause of the ulceration must be analyzed. Methods of preventing recurrent ulceration can be deduced from a study of the mechanism resulting in ulceration. Often it is obvious, such as infected wounds and cracks. In these cases general foot- and skin care is of uttermost importance in preventing re-ulceration. Another large group of ulcers has a tendency to persist without treatment and rest, and to relapse on the resumption of walking with a considerable risk of deep infection and consequent deformity and destruction of the foot. Such ulcers are usually pressure sores over a bony prominence. In such a case, to perform skin grafting or to do a beautiful flap

without being able to reduce the pressure of which the ulcer was caused, is useless and a waste of time. Only footwear modification or bone surgery, or both can reduce the harmful pressure in such areas. The surgery may consist of simple osteotomy of a bone spur or an arthrodesis to realign the foot.

METHODS OF COVERAGE OF ULCERS

Distant Skin Flaps

Multiple distant flaps (i.e. cross thigh flaps, cross groin flaps, buttock skin flaps, free muscle flaps covered with split skin graft) with tissue not specialized to withstand walking, are described in the literature to cover plantar defects. Patients with normal plantar sensation might to some extent be able to protect such tissue somehow by avoiding full weight bearing during the cycle of walking. However, distant flaps are seldom indicated in leprosy. These patients have feet that lack protective sensation and they need to be able to walk a lot. Distant flaps will not be further described in this chapter with the exception of the medial cross-plantar flap, which I personally have found quite useful.

Local Muscle Flaps

Different local muscle flaps like abductor digiti minimi, abductor hallucis brevis and flexor digiti minimi muscle covered with skin graft are usually of little value since these intrinsic muscles are usually atrophied in the neurologically impaired foot. These flaps will not be further described.

Transposition and Rotation Skin Flaps of the Sole of the Foot

Fascio-cutaneus flaps, i.e. flaps consisting of skin, subcutaneous tissue as well as plantar fascia have been recommended in older leprosy textbooks.[7]

With the exception of the medial plantar island flap, I personally do not have much experience with such flaps. However, the results I have seen done by other surgeons have not been convincing (Fig. 16-7).

In inexperienced hands, these big fasciocutaneous flaps can easily leave the patient in a less favourable situation. However, similar but thinner flaps where the plantar fascia is not included can work well. These are flaps consisting of epidermis, dermis and the specialized fibro-fatty pad overlying the plantar fascia. The dissection is more superficial and technically simpler to do than a fasciocutaneous flap based on an axial vessel, i.e. the medial plantar flap. These superficial flaps must be considered random flaps. The blood supply does not permit an immediate transfer, so they need to be delayed. The flaps should in most cases be laterally based, leaving the donor area with a skin graft in the non-weight bearing medial aspect of the foot. The preferred method of delay might be incision of skin and sub-cutaneous tissue only without undermining the flap, and then re-suturing. After 2 or 3 weeks the flap is transferred into the defect. A split skin graft is applied to the donor area.

Skin Grafting

When an ulcer or defect is due to loss of skin only (e.g. burns), split skin grafting is a useful primary treatment for large and clean granulating ulcers on the sole. In these cases, a layer of plantar fascia and padding remains intact between the graft and the underlying bone. In the non-weight-bearing areas like the instep a split-skin graft can usually be applied successfully even when the pulp consisting of subcutaneous tissue and fascia is missing.

SPECIFIC PROCEDURES

The specific procedures for coverage of ulcer defects on the sole are described below, divided by anatomic region.

Heel Coverage

Small or superficial defects can usually be treated with rest, application of a plaster cast, or simple split skin grafting. In case of a chronic sinus leading down to the bone or the plantar fascia attached to the calcaneus, so-called calcaneal paring is indicated (see Chapter 15). For small deep ulcers a V-Y plasty or delayed cutaneous transposition flap can also work well (See below).

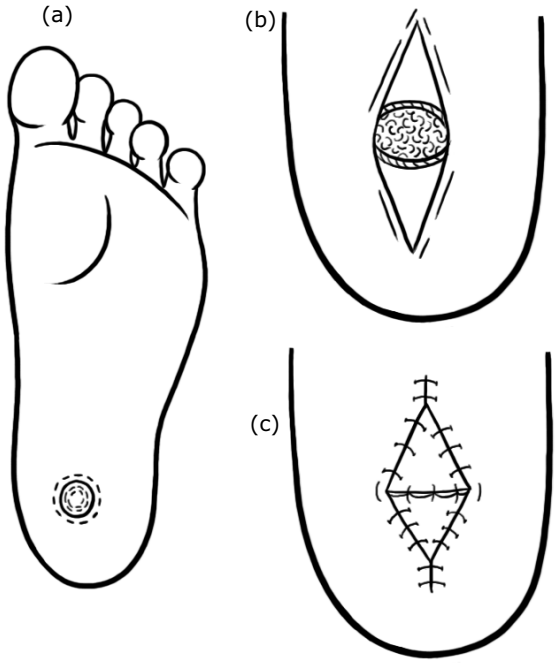

FIGURE 16-1 Small deep heel ulcer covered with opposing V-Y flaps. Because there is absolutely no undermining with the local V-Y flap, its mobility is restricted by underlying tissue and can usually be advanced only 1-1,5 cm. To expand the size of the defect that a single V-Y flap can cover, two opposing V-Y flaps can be designed. The larger the V-Y, the better is the blood supply and the more the flap can be advanced.

The large heel defects, which sometimes present with total loss of soft tissue and bone involvement as well, have too often been an indication for below knee amputation. Large local fascio-cutaneus transposition flaps recommended in older textbooks might be sufficient to cover smaller defects, but frequently these flaps just do not reach to the area where the tissue is needed the most. Furthermore, the scar left by a poorly designed flap can add an additional problem to the function of the foot.

Laterally based transposition flaps for heel coverage

Alternatively, a laterally based skin flap can be applied (Fig. 16-2).[3,7]

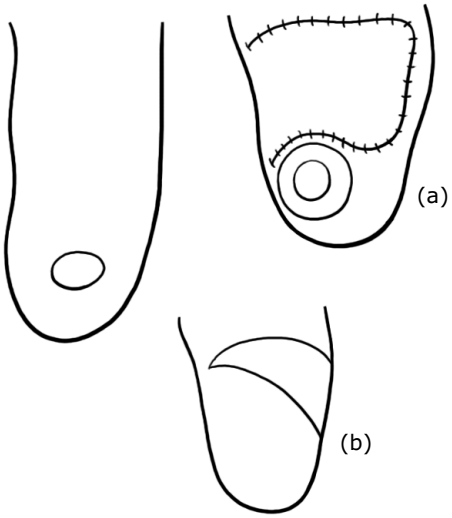

FIGURE 16-2 A relatively small heel defect can be covered with a laterally based transposition flap. **a.** Delay procedure is performed **b.** Surgical correction with excision of ulcer and surrounding scar. The previously delayed flap is transposed into the defect and the donor area is covered with split skin graft.

Medial plantar island flap for heel coverage

This flap has proved to be reliable and extremely useful for heel reconstruction in leprosy (Fig. 16-3).[5] Hence, it will be described in detail. It should be stressed, however that the dissection is not easy and that some familiarity with more complicated plastic surgical procedures as well as microsurgery is an advantage.

General surgeons with some experience in basic plastic surgery should be able to perform the operation safely after necessary exposure. Learning to utilize this flap is well worth the effort.

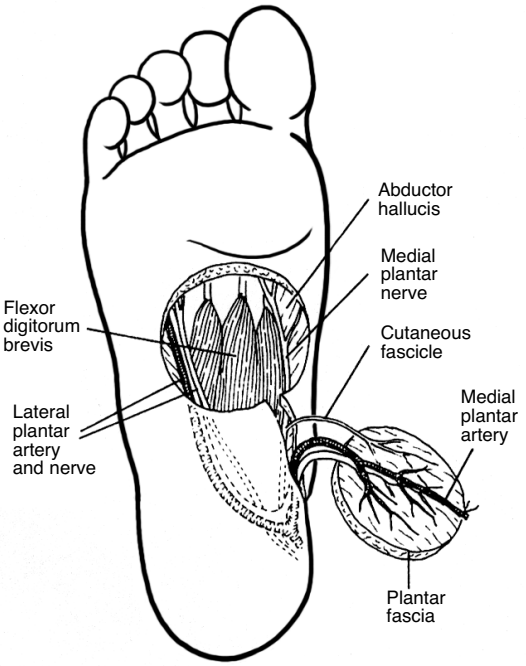

FIGURE 16-3 Anatomy and dissection of the flap.

Indications

This flap is recommended as a standard method for heel reconstruction in most cases where there is major loss of soft tissue. It can be used for recurrent ulcers as well as squamous cell carcinomas of the heel. The posterior tibial artery must be patent. Dorsalis pedis artery or the peroneal artery must also be patent.

Anaesthesia

A spinal or general anaesthesia is usually necessary.

Procedure

The position and route of the posterior tibial artery is marked prior to surgery (Figs. 16-3, 4a). A Doppler can be helpful in this. The patient is placed in a prone position, and a tourniquet is applied. The heel ulcer should be debrided, if necessary debridement could be performed some days prior to the coverage procedure. The ulcer, together with surrounding scar tissue should be excised and the underlying bone should in most cases be trimmed to make sure the bony surface is smooth and healthy. A circular defect is easiest to cover. The flap, which is based on the medial plantar vessels, is planned just proximal to the weight bearing area of the metacarpal heads. The diameter of the flap should correspond to the size of the heel defect and there is no reason to oversize it. A line is drawn from the centre of the flap to the area behind the medial malleolus where the posterior tibial artery was felt before the tourniquet was applied. Then a second line is drawn from the centre of the heel defect to the medial malleolus. The flap is first incised distally down through the subcutaneous fat and the plantar fascia, then in the same manner laterally and medially. Proximally, the incision should be more superficial so as not to destroy the pedicle. Deep intra muscular septa have to be divided in order to raise the flap. The medial plantar nerve can be visualized, and in most cases it can be cut distally and included in the pedicle. This makes the dissection simple and reduces the risk of injuring the vessels. In rare cases, with intact protective sensation of the forefoot, one could consider to retain the nerve in the foot while the cutaneous fibres to the flap itself are peeled off the main nerve. This kind of dissection needs loop magnification. Knowing the direction of the vascular pedicle, a strip of soft tissue about 2 cm wide located between the short muscles of the foot and the plantar fascia will incorporate the vessels. Some deep septa under the pedicle need to be divided. Where the pedicle goes under the abductor hallucis muscle this muscle sometimes needs to be divided in order to make the

pedicle long enough to allow the flap to be transposed smoothly into the heel defect without any tension. It is recommended to make the incision from the heel defect towards the pedicle quite deep, and to do this prior to the dissection of the pedicle itself (Fig. 16-4b). Some undermining of the soft tissue between these incisions will make the flap reach the heel more easily, and one can avoid the most proximal and hazardous dissection of the pedicle. When the pedicle is long enough, the flap is transposed and the tourniquet is released (Fig. 16-4c). After a few minutes of light compression, the bleeding is controlled with a bipolar cautery and a rubber drain is left to drain the pedicle and flap area. The incisions are closed with interrupted 3-0 stitches before the donor area is covered with a split skin graft. A compressing dressing is applied on the donor area with the skin graft while a rather loose well-padded dressing, possibly with a window for inspection is applied on the heel itself.

After-Care

An adequate prophylactic antibiotic should be given pre- and postoperatively for a few days. The rubber drain is pulled out after 2-3 days, and the whole dressing can be changed after 5-7 days. During this period the patient should have strict bed rest with the foot slightly elevated. Walking without weight bearing is then gradually allowed, and the stitches are removed after 2 weeks time. In most cases full weight bearing is allowed after four to five weeks. Results are shown in Figs. 16-5 and 16-8.

There is a possibility that removal of the plantar fascia weakens the support of the foot and hence predisposes for collapse of the arch later on. In case arch support is considered it is important to wait up to 3 months time in order to let the split skin graft of the donor area gain

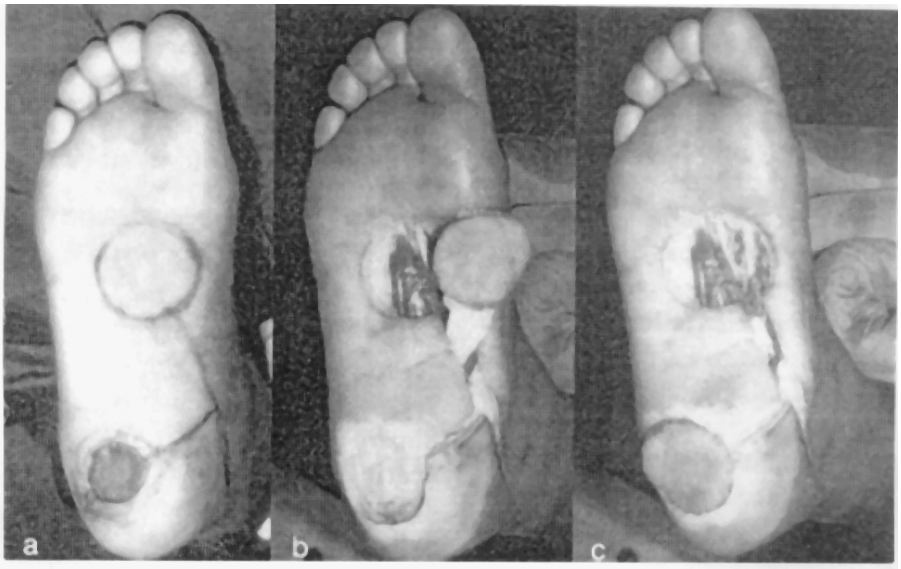

FIGURE 16-4 **a.** Preoperative marking in an 18 year old girl with an ulcer of 2 years duration. Notice how the scar tissue surrounding the ulcer is excised with the ulcer and how the flap is constructed just proximal to the weight-bearing region of the metacarpal heads. A line is drawn from the posterior tibial artery behind the medial malleolus to the centre of the planned flap. Another line is drawn to mark the incision for the tunnel of the pedicle. **b.** The flap consisting of skin, subcutaneous fat, and a thick well-defined plantar fascia is raised on the vascular pedicle. Note the bulk of the pedicle containing the vessels. **c.** The flap is transposed smoothly to the defect without tension or kinking.

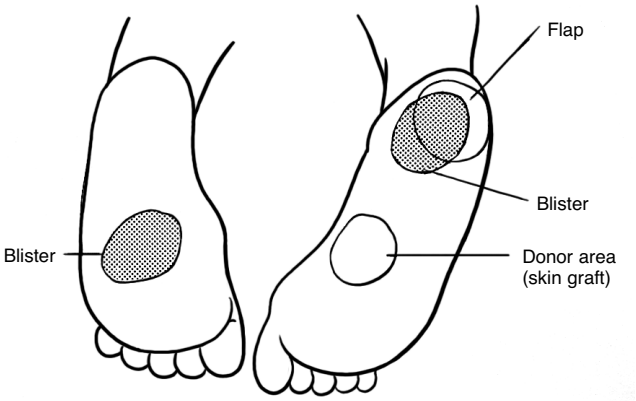

FIGURE 16-5 A 33 year old man operated for an ulcer of the right heel 4 months previously. His left foot was "boatshaped" because of collapse of the longitudinal arch. A 10 km long walk resulted in haemorrhagic blisters (dark area of left midfoot and right heel). Notice how the blister of the right heel is affecting the flap and surrounding tissue equally, indicating that the quality of the flap is similar to that of the native soft tissue of the heel.

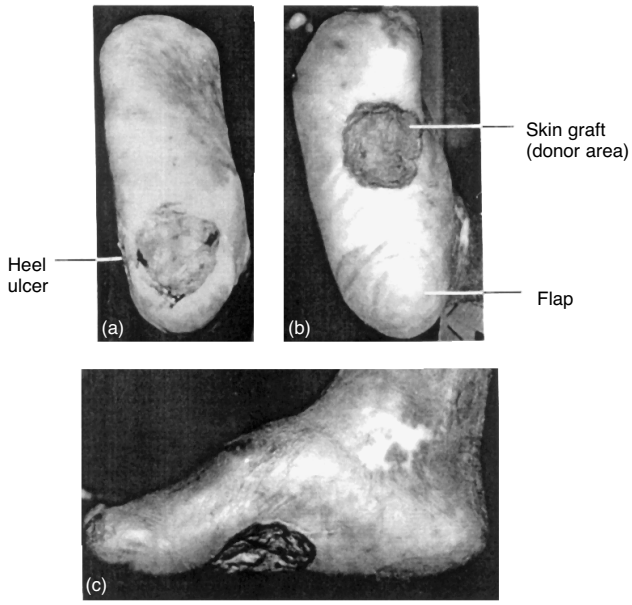

FIGURE 16-6 **a.** Extensive heel ulcer with total loss of soft tissue of 8 years duration in a 48 year old man. **b.** 8 months after reconstruction the heel looks normal with an excellent result including good stability.

sufficient stability and strength to take the pressure from the inlay device. The defect left by the removal of subcutaneous tissue will have filled in by that time.

Cross-Foot Flap for heel coverage

In case the instep of the same foot is not suitable for a flap harvest, it is possible to raise the medial plantar flap from the contra lateral foot (Fig. 16-7). An external osteo-fixation between the tibias as well as a K-wire between the two calcaneal bones will keep the legs in a stable position until the pedicle is safely divided after two weeks. Alternatively, plastering can be used to hold the position but is difficult to maintain.

Midfoot Coverage

Defects on the medial aspect of the plantar surface are non-weight bearing and are best treated with skin grafts. If there is an underlying bone causing an existing midfoot ulcer, as usu-

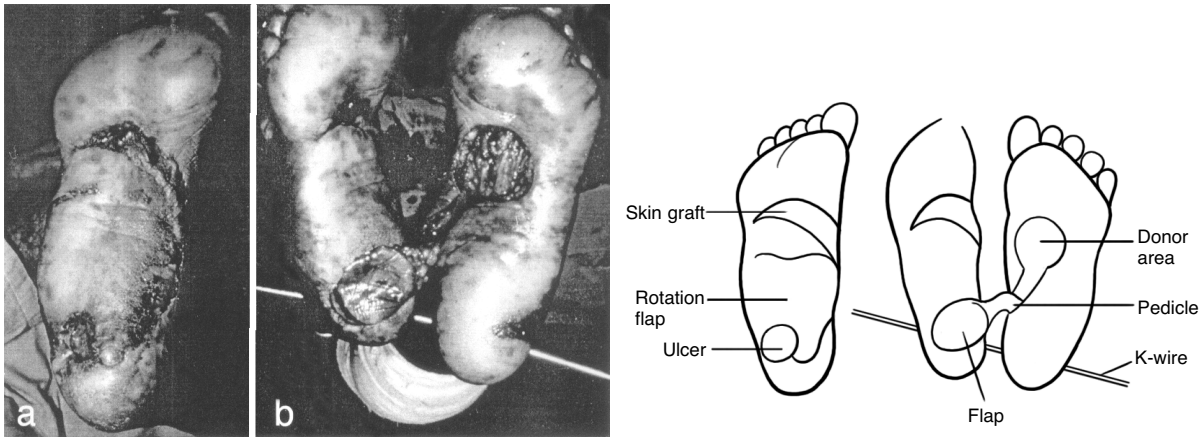

FIGURE 16-7 **a.** The plantar area in a 40 year old woman who had a huge laterally based fasciocutaneous transposition flap raised 3 years previously. Notice new ulceration of the heel area. **b.** Operative picture showing adequate length of the vascular pedicle reaching from one instep to the opposite heel. External osteofixation between the two tibias and a K-wire through the calcaneal bones kept the legs in a stable position until the pedicle was safely divided two weeks later.

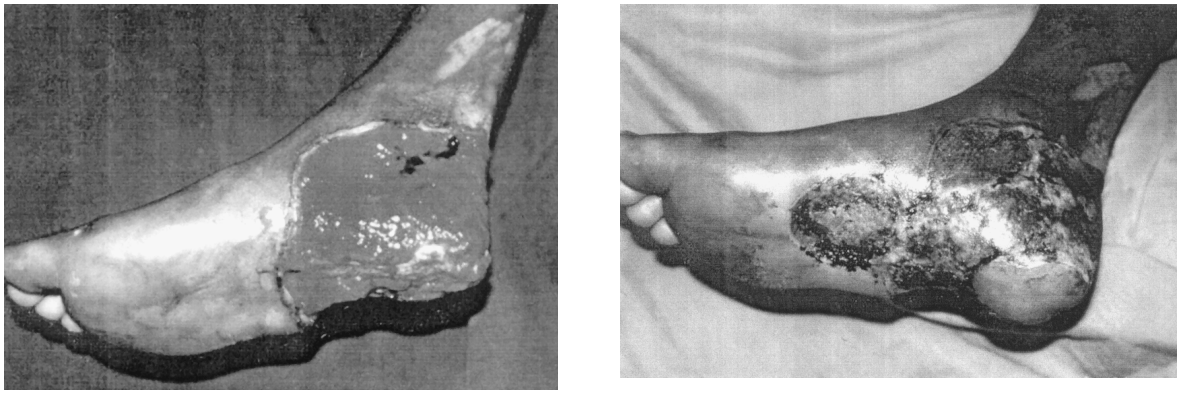

FIGURE 16-8 Pre- and postoperative pictures in case of an extensive avulsion injury in 25 years old non-leprosy patient. The weigh-bearing area of the heel is covered with an island flap from an intact distal instep. The donor area as well as the remaining raw area is covered with split-skin.

ally occurs with a collapsed Charcot foot, the excess bone can be shaved via a lateral or medial approach or sometimes directly through the ulcer during debridement. The ulcer can be either allowed to heal by secondary intention or addressed depending on its size. For small defects, a V-Y flap can be useful, while for larger defects large medially or laterally based delayed random flaps can work well (See type of flaps).

Once healed, the patient with a Charcot foot has to be considered for a possible mid/hind foot fusion so that the breakdown will have less chance of recurring.

Forefoot Coverage

For small ulcers over the MTP joint without bone involvement a pressure point reduction procedure (see Chapter 15) is usually sufficient for the ulcer to heal by secondary intention.

Small deep forefoot ulcers without an obvious bony prominence can also be covered with a local flap: a filleted toe flap, (Fig. 16-9) a toe island flap (Fig. 16-10), a V-Y flap[2] (6)or a larger rotation flap (Fig. 16-11).

Using soft tissue from a toe:

Indication: Small and deep recurrent ulcers of the forefoot, usually under the metacarpal heads.

In leprosy, functionless toes, subluxated appendages with their own risk of friction ulceration can serve the foot instead of being a troublesome liability. Generally, the soft tissue of the toe is used in the flap, discarding the skeleton. Alternatively, if the toe has a normal shape and size, one-half of the toe skin based on one neurovascular bundle could be used, grafting the resulting defect on the toe. For replacement of a defect in the metacarpal head area the soft tissue of the toe might be hinged at the level of the transverse plantar ligament, although it can be hinged as far back as the plantar arch if dissection deep to the toe flexors is involved.

Filleted Toe Flap (Fig. 16-9)

Technique: The plantar ulcer with surrounding scar is excised, leaving edges of healthy tissue. The toe is incised dorsally and the soft tissue is dissected from the skeleton, visualizing the neurovascular bundles. The toe skeleton can now be excised. The metacarpal head should be trimmed or removed, depending on the condition of the forefoot. The neurovascular bundles are then mobilized, dividing the transverse ligament. After freeing the skin, the flap is hinged into the defect. Excess toe skin might need to be resected.[4,8]

Toe island flap (Digital Artery Island Flap (Fig. 16-10)

Based on one of the neurovascular pedicles this flap can close small forefoot ulcers.

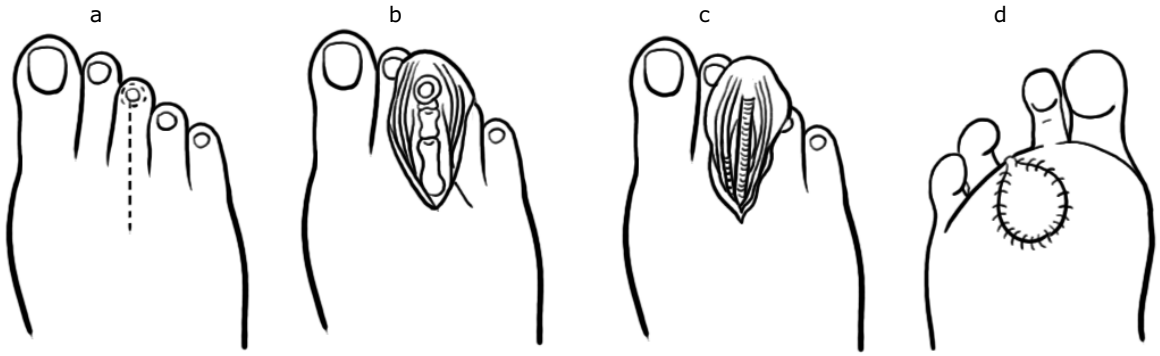

FIGURE 16-9 Toe island flap (Digital Artery Island Flap) **a, b.** Dorsal incision with excision of nail **c.** Excision of bone **d.** Final result.

Technique: The flap consisting of skin and subcutaneous tissue is designed on the side of the toe avoiding the nailbed and including only part of the plantar area of the toe. The incision is extended through the plantar pad of the forefoot, and the neurovascular bundle that lies on the side of the flexor tendon is mobilised. As for the filleting toe flap, the transverse ligament must be divided. When the pedicle has sufficient length, a subcutaneous tunnel is created to the ulcer area; the island flap is transposed and sutured. The donor area of the toe is cov-

ered with a skin graft.

V-Y Plasty for forefoot coverage

See V-Y Plasty for coverage in the heel area. (Fig. 16-1) The principle as well as the limitations is much the same in the metacarpal areas.

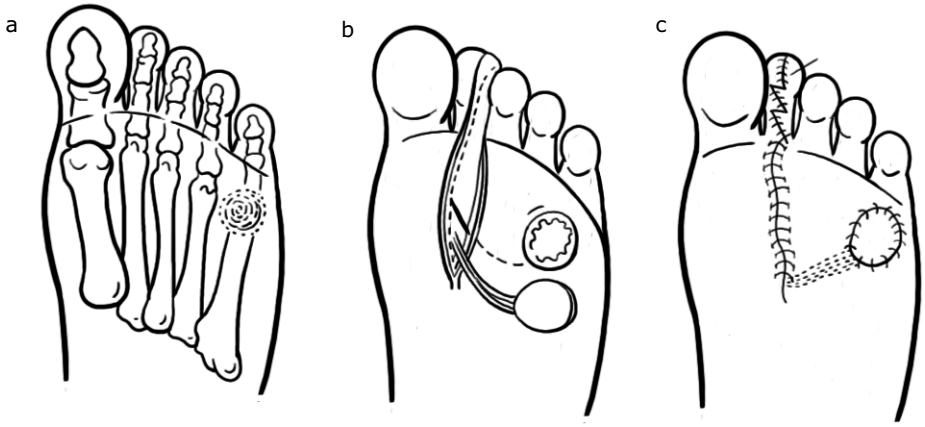

FIGURE 16-10 Digital artery island flap. **a.** Site of ulcer under 5th metatarsal head. **b.** flap raised from site of toe based on neurovascular pedicle. **c.** Flap insert, skin graft sutured over defect.

Reversed medial plantar island flap for forefoot coverage

A modification of the medial plantar flap is also described to cover the distal weight bearing area of the foot. The standard medial plantar flap described above derives its blood supply from the medial plantar artery, a terminal branch from the posterior tibial artery. The modified flap gets its blood supply from a reversed flow in the lateral plantar artery and vein. This flap is probably most useful after trauma and tumour resection, but occasionally the neuropathic foot might present a huge ulcer or unstable scar on the forefoot area where this flap might be used. Technically it is more complicated to raise the reversed flap than the standard flap, and the surgeon should be familiar with the latter before trying the more complicated reversed one. The operation will not be described in detail in this chapter, but interested readers might find out more about this flap described by Martin and coworkers.[8]

Laterally based Transposition Flap for forefoot coverage (Fig. 16-11).

Indications: Recurrent ulcers of the medial and central forefoot.

Technique: See discussion above regarding rotation flaps in the foot. A laterally based flap starting just posterior to the ulcer is cut down to fascia and sutured. Two weeks later the ulcer with surrounding scar is excised, the flap is raised in a plane just superficial to fascia. The flap is then rotated into position and sutured. The defect on the non weight-bearing instep is skin grafted. Post-operative care is as for the medial plantar artery flap.[3]

Summary

In the neurologically impaired foot pressure ulcers are common. Pressure point reduction must always be addressed. Most ulcers, perhaps with the exception of huge heel ulcers, will heal by secondary intention if treated conservatively in the right manner. However, conservative treatment can be very time consum-

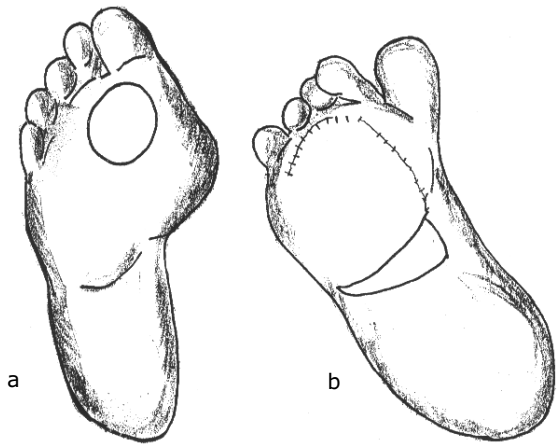

FIGURE 16-11 Lateterally based fascio-cutaneous flap. **a.** large medial forefoot ulcer **b.** Flap raised and sutured into defect with skin graft to donor area.

ing and might sometimes leave unstable scars. For those with recurrent ulcers, the time taken off work to heal these ulcers can be economically debilitating. Skin grafting and flap coverage can be rewarding in selected cases. Follow up with proper footwear is of uttermost importance.

Soft tissue coverage can only occur when all signs of infection have resolved and the foot has an adequate blood supply.

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