CHAPTER **36**

ORTHOPLASTIC FOOT AND ANKLE RECONSTRUCTION PART I: Skin Grafting

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By definition, a skin graft is a transplanted piece of the epidermis and varying portions of the dermis from one region of the body to another. The blood supply to the transplanted skin is obtained from the recipient site as this tissue is incorporated in its new environment. In general, skin grafting is used when other methods of reconstruction such as primary closure, second-intention healing, or local skin flaps are inappropriate, unavailable, or would produce a suboptimal cosmetic or functional postoperative result. Applications in foot and ankle surgery include ulcer coverage, burn reconstruction, traumatic soft tissue loss, rotational or free muscle flap coverage, and desyndactylization, among others.

Skin grafts can be classified by graft species (e.g., autograft, isograft, etc.), and further by graft thickness. The latter is divided into 2 major categories: full-thickness skin grafts (FTSGs) and split-thickness skin grafts (STSGs). A FTSG includes the epidermis and entire dermis, and will vary in thickness depending on the donor site. STSGs may be subdivided into thin (0.008 to 0.012 inch), medium (0.012 to 0.018 inch), and thick (0.018 to 0.030 inch) grafts.

STSGs are most commonly used when cosmesis is not a primary concern or when the defect to be corrected is of a substantial size that precludes the use of a FTSG. STSGs are often used as coverage of chronic non-healing cutaneous ulcerations, coverage of local or free muscle flaps, and coverage of burn areas to accelerate wound healing and to reduce fluid loss. These grafts can be harvested from locations such as the buttocks, thigh, calf, and abdomen.

FTSGs can be used to achieve excellent cosmetic and functional outcomes when the donor site is selected appropriately and when both the donor graft and recipient bed are carefully prepared before the graft is transplanted. The use of FTSGs is indicated for defects in which the adjacent tissues are immobile or unavailable. FTSG use is also indicated if the adjacent tissue has pre-malignant or malignant lesions and precludes the use of a flap. Examples of the use of a FTSG in the foot are minigrafting (punch grafting) for the surgical correction of depigmenting conditions, for skin replacement after excisional skin biopsy, or in desyndactylization procedures. The differences between STSGs and FTSGs are summarized in Table 1.

SKIN GRAFT INCORPORATION

Skin graft incorporation, termed graft "take," is the process of adherence and acceptance of the graft by the host bed. This process has been divided into three phases: plasmatic imbibition, inosculation and neovascularization, and revascularization/reinnervation. The initial stage of graft healing, termed plasmatic imbibition, occurs within the first 24-48 hours after the placement of the graft on the recipient bed. During this process, the donor tissues receive their nutrition through the absorption of plasma from the recipient wound bed via capillary action. In this phase of healing, the graft is pale and may appear somewhat edematous. This is because venous and lymphatic circulation to the graft is absent at this point, and the graft capillaries stay dilated due to the plasmatic influx. A fibrin

Table 1

COMPARISON OF FULL-THICKNESS AND SPLIT-THICKNESS SKIN GRAFTS

Full Thickness	**Split-Thickness**
Least chance of graft take	Best chance of graft take
Least amount of contraction	Most tissue contraction
Most functioning dermal glands	Fewest (if any) functional glands
Best chance of complete reinnervation	Will usually retain some element of hypesthesia/anesthesia

network is also created between the graft and the recipient bed during this phase, and the recipient bed generates vascular buds that grow into the fibrin network.

Because there is no true connection between the graft and the host during this stage, this fibrin network helps the graft adhere to the host bed. Moreover, because nutrients can be absorbed more effectively over shorter distances, thinner grafts tend to survive better in this stage of graft healing. The most common complication leading to graft failure is hematoma or seroma collection beneath the graft; this development will prevent successful osmotic nutrient transfer between the host bed and the graft. This complication is most likely to occur during this period, and consequently strict attention must be paid to prevent hematoma formation and address this process if it does occur.

After the initial 48-72 hours, a period of inosculation and neovascularization begins. This phase may continue for as long as 1 week after grafting. During this time, the vascular buds from the host bed anastomose with both preexisting (inosculation) and newly formed vessels (neovascularization). This revascularization of the skin graft, which occurs more rapidly in a STSG than in a FTSG, is initially accompanied by a mottled and then an erythematous appearance. The pinkish hue is due to the formation of fine new blood vessels and capillary anastomoses on the undersurface of the graft. By the ninth day, the new vascular architecture firmly anchors the graft to the recipient bed. Occasionally the graft may appear slightly cyanotic during this phase, especially in the presence of secondary revascularization where there is a lack of graft-host apposition. A unique phenomenon of vascular bridging has been described to account for revascularization in relatively avascular recipient beds. In this situation, vascular ingrowth occurs from the relatively highly vascularized lateral aspects of the recipient bed and bridges across the avascular base of the recipient bed. However, for vascular bridging to occur, the recipient area must remain small, and the area that immediately surrounds the graft must be highly vascularized. Small (<5mm) sections of exposed bone or tendon devoid of periosteum or paratenon may be grafted in this manner.[1]

The phase of revascularization/reinnervation encompasses the period from when the first true vascular communication between the graft and host begins until full incorporation of the graft to the bed occurs. Lymphatics and veins develop in the graft tissue at approximately 1 week after transplantation, and are functional by the 9th day. Reinnervation of the graft may begin as early as the first few weeks, although many grafts may have some degree of permanent anesthesia. Reinnervation is most complete in full thickness grafts, where complete return of sensation is possible, and least complete in thin STSGs.

RECIPIENT SITE PREPARATION

The key to successful skin grafting is adequate preparation of the recipient bed. Thus, a clean, vascular wound bed is necessary, without excessive bleeding or local tension. A chronic or infected wound should be freshened through curettage and sharp debridement and converted to a clean, acute wound. Wound edges, the wound bed, and any exuberant granulation tissue that forms are debrided because this may be a site where bacteria may hide. High pressure pulse lavage with several liters of saline is performed as needed. For dirty or severely infected wounds chlorpactin (2g/L) or bacitracin (50,000U/L) is added to the saline irrigant. A wound bed of muscle or fascia is preferred to a bed of fat, and will provide for more reliable take of the graft. If only fat is present, it is preferred to wait for granulation tissue to form before grafting, although this tissue is debrided prior to grafting to minimize potential infection. This process may require multiple trips to the operating room. In between surgical debridements the wounds are left open and dressed with moist sterile sponges to protect the wound from further contamination and tissue dessication.

HARVESTING A SPLIT-THICKNESS SKIN GRAFT

The entire extremity on the affected side is prepped and draped, and the patient is placed in the appropriate position for access to both donor and recipient sites. Drapes should allow for access to the harvest site and unimpeded movement of power instrumentation along the skin. The donor site is shaved, and infiltrated with lidocaine with dilute epinephrine. The recipient site is prepared as described above. Freshening of the wound edges can be performed simultaneous with skin transplantation however it is paramount to establish adequate hemostasis prior to grafting. The wound is measured after debridement.

The Zimmer™ power dermatome is set up for harvesting the desired thickness graft. We use 0.015 inch grafts regularly and set the dial on the dermatome accordingly. Sterile saline is applied to the donor site with a sloppy wet sponge, and the dermatome is applied to the skin at a 60 degree angle beginning distally, with manual tension applied proximally in a cephalad direction. The

dermatome is laid down to approximately an 80 degree angle, and advanced slowly with even pressure until an adequate-sized graft is harvested. The dermatome is then turned sharply upward to cut the leading edge, and the entire graft is removed as one piece from the donor site. Inspection of the graft should reveal a uniform thickness piece of skin, ideally without torn or ragged edges.

The graft can be meshed if needed (Figure 1). Meshed grafts have the advantages of allowing for smaller grafts to fill larger spaces and allowing fluid from the wound bed to drain through the graft rather than accumulate beneath it. We generally mesh skin grafts to 1:1.5 times with a hand mesher. The graft is placed on the smooth side of a meshing plate, and spread evenly atraumatically with the back of a blade handle or tissue forcep handle. The graft may be placed dermis or epidermis side down, however care must be taken at the time of application to be sure the shiny dermis side is down against the recipient bed. "Pie crusting," making multiple small incisions into the graft with a sharp blade, is another method for allowing drainage through small grafts (Figure 2). However, there is no gain in any appreciable additional size of the graft with this method.

The meshed graft is then applied gently to the wound bed, dermis side down, overlapping on all sides. The back of a #3 blade handle is useful for helping tack the graft in place, especially around corners and in crevices. The graft is then secured with suture to the wound edges, and through the midsubstance of the graft if necessary. We use 4-0 chromic suture in running fashion along the periphery on the graft. Small guage absorbable monofilament suture such as Monocryl® is also an excellent choice of suture for this application. Excess graft is then trimmed from the edges. If a stent dressing is to be applied, large guage (2-0 or 3-0) polypropylene suture is tied in to the tissue peripheral to the graft (not through the graft) on opposite sides, and tied over the dressing.

A dressing is applied directly to the graft to protect and apply gentle even pressure to the graft. A one-ply layer of Xeroform® (Sherwood Medical Industries, St. Paul, MN) dressing sits immediately over the graft, and then sterile mineral oil or saline-soaked cotton balls are compressed and placed against the graft. The edges of the Xeroform® dressing can be folded over the cotton balls and secured with stent sutures or additional dressing. Sterile 4X4 gauze squares and Kerlix® are applied under light tension. Immobilization through a modified Jones-type dressing or posterior splint with minimal compression is applied to the extremity to prevent shearing of the graft. (Figures 3-12)

HARVESTING A FULL-THICKNESS SKIN GRAFT

For small defects in the foot punch or pinch grafting is an excellent option because these small grafts can be obtained from the redundant skin on the ipsilateral foot. The most common sites for obtaining small full thickness pieces of skin from the foot are the sinus tarsi, dorsum of the first metatarsophalangeal joint, and the plantar instep. All of the grafts are harvested in the same manner.

An appreciation for the relaxed skin tension lines is critical to prevent excessive tension on the donor site that will be primarily closed. In general these lines correspond to an axis perpendicular to the long axis of pull of the underlying tendons. On the dorso-lateral foot, these lines

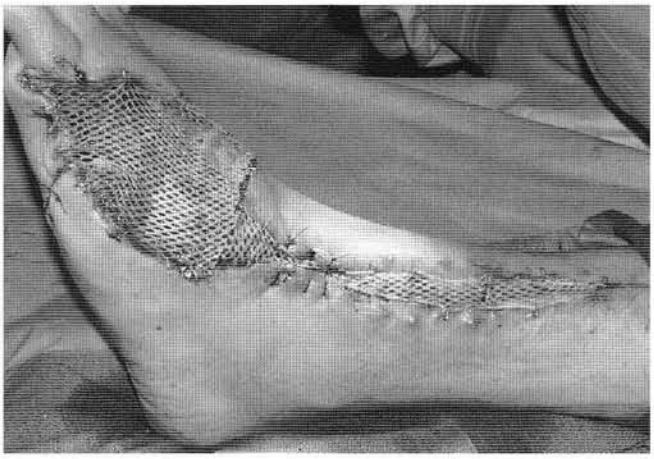

Figure 1. Meshing a split-thickness skin graft allows for coverage of larger defects and for drainage of fluid from beneath the graft. This type of graft is appropriate for most applications on the dorsum of the foot and leg.

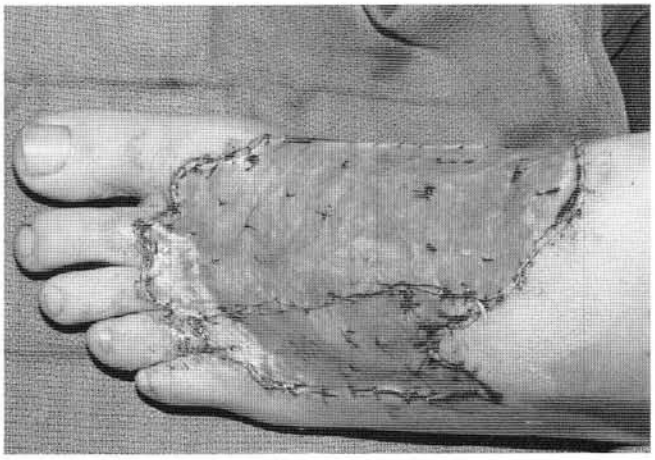

Figure 2. Pie crusting a STSG with a sharp blade is another method for allowing drainage through the graft. The disadvantage of this method is that there is no appreciable increase in graft size obtainable.

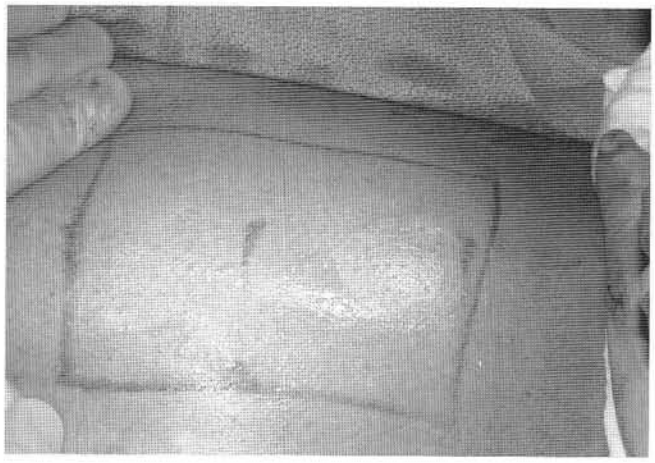

Figure 3. The ipsilateral extremity is prepped and draped for access to the donor site. Measurements of the wound are obtained for gross estimation of the size of the graft needed. The skin surface is marked and the power dermatome is placed at the distal extent.

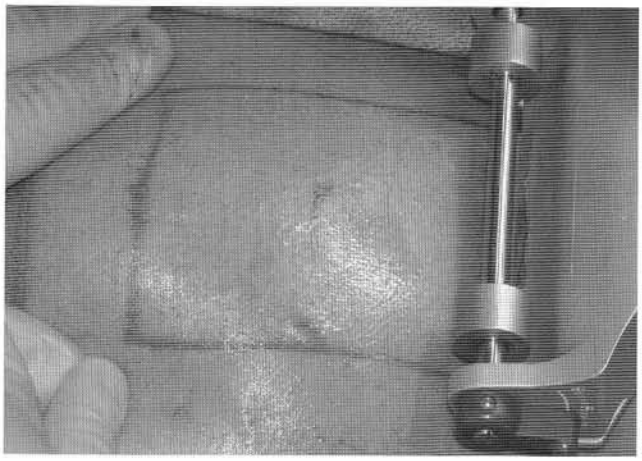

Figure 4. The dermatome is placed at 45 degrees to the skin to cut in to the epidermis.

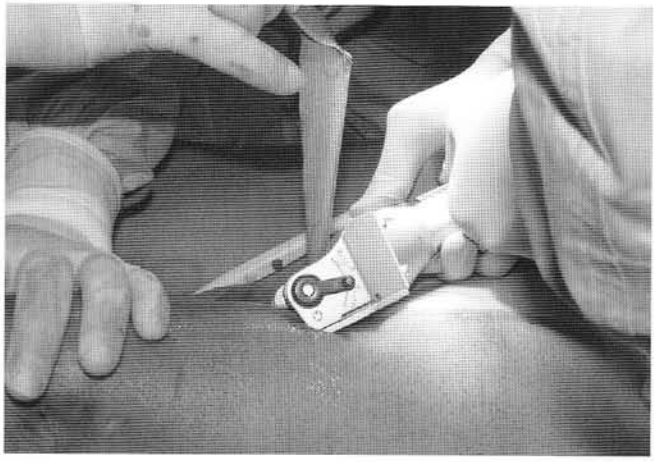

Figure 5. The dermatome is then angled to 80 degrees while advanced in a cephalad direction with the skin held under tension. When an adequate graft size is obtained, the dermatome is turned sharply upward to cut the leading edge of the graft.

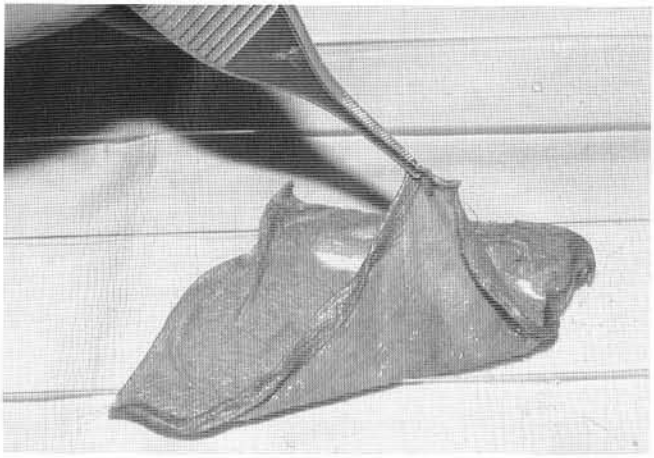

Figure 6. Once the graft is harvested, it is placed on the smooth surface of a meshing plate with the shiny dermis side down.

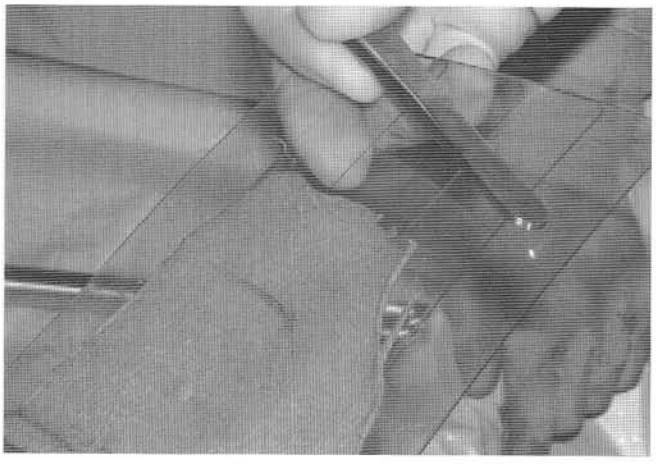

Figure 7. The skin is atraumatically smoothed over this plate using the back of a blade handle until all bubbles and edges lay neatly against the plate.

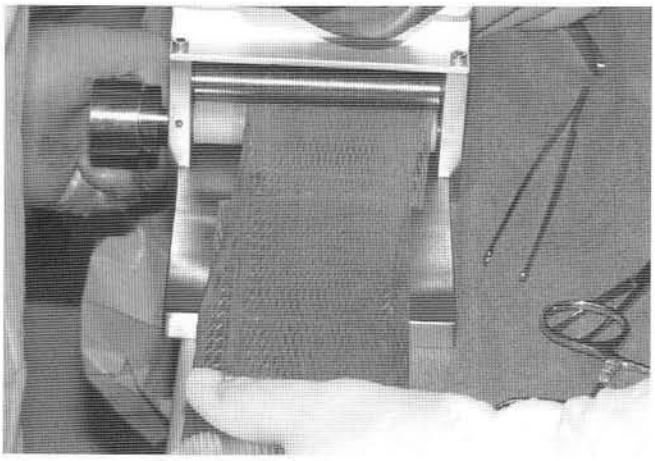

Figure 8. The graft and plate are then sent through the hand mesher set at 1.5X.

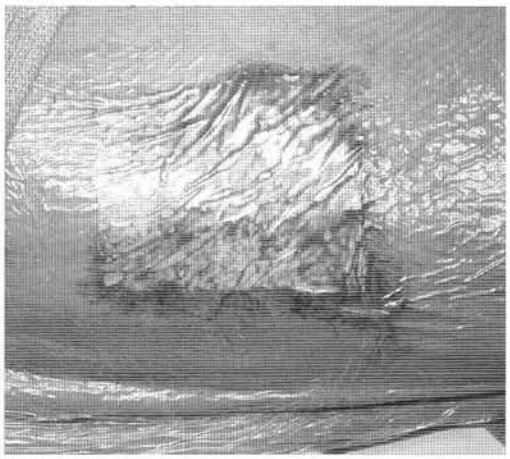

Figure 9. The donor site is dressed with a transparent occlusive dressing. Prior to dressing application the field can be sprayed with a topical hemostatic agent such as thrombin or epinephrine. This dressing is maintained while epithelialization occurs.

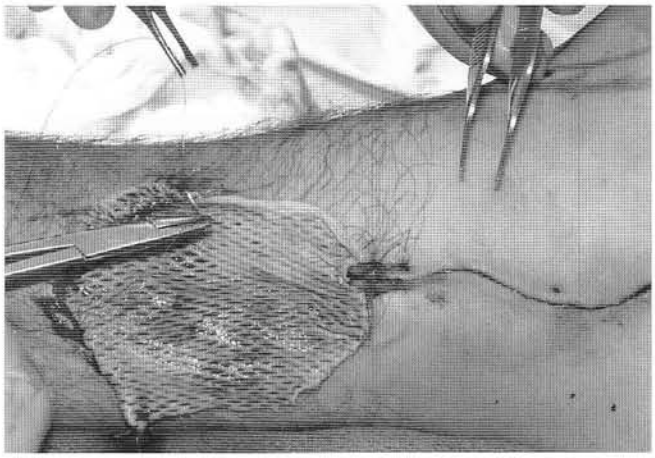

Figure 10. The skin graft is applied to the wound with complete contact of the dermis to the wound bed. The graft can be stretched and cut to fit as needed.

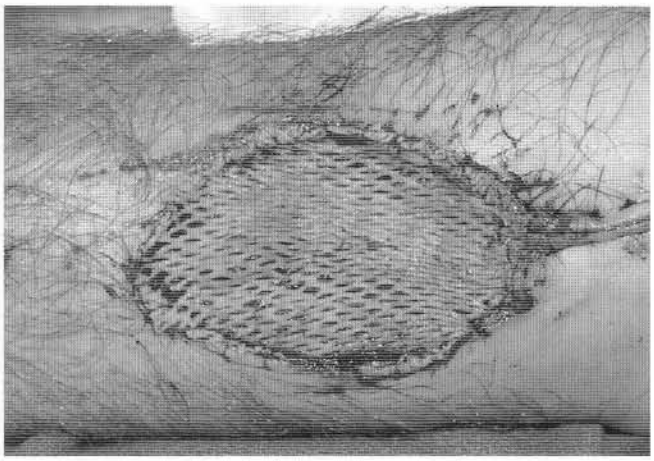

Figure 11. The graft is sewn in place with running interlocking absorbable suture around the wound periphery. If regions of the graft pucker or do not completely adhere to the wound bed suture is placed through the graft mid-substance to maintain graft apposition.

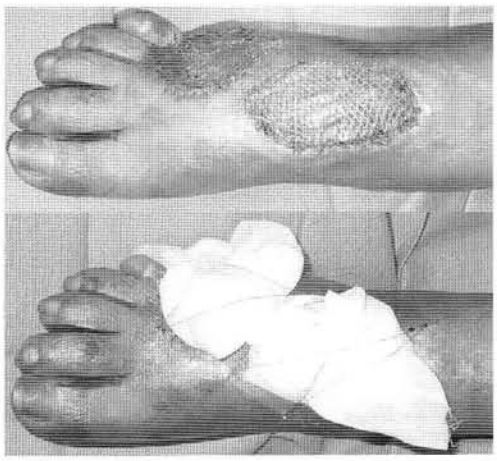

Figure 12. The graft is then dressed with a non-adherent, absorbent dressing. Stent dressings are utilized to maintain even compression and graft apposition. This can be accomplished through evenly spaced mineral-oil soaked cotton balls and a peripheral suture technique. A STSG was placed here on the dorsum of the foot and stent tie-over sutures over Xeroform® and cotton balls are demonstrated.

run in an oblique direction from dorso-medial to plantar-lateral. A football-shaped graft can easily be harvested from this region without closure under excessive tension.

Local anesthesia with dilute epinephrine is infiltrated through the donor site. An incision is made through the epidermis and dermis to the subcutaneous layer beneath. Atraumatic forceps are used to manipulate the appropriately sized graft, while the dermis and subcutaneous fat are separated. Any of this fat is gently trimmed from the graft with small curved metzenbaum or tenotomy scissors prior to transplantation.

The graft is secured to the wound bed in the same manner described for split-thickness grafts. Care is taken to minimize tensile or shearing forces on the graft intra-operatively and postoperatively. (Figures 13-17)

POST TRANSPLANTATION

The immediate postoperative course is extremely important to a successful outcome. For the first 3 to 4 days, the graft receives nutrition via diffusion of materials, creating a "semi-permeable membrane" effect.[2] Failure of graft take is

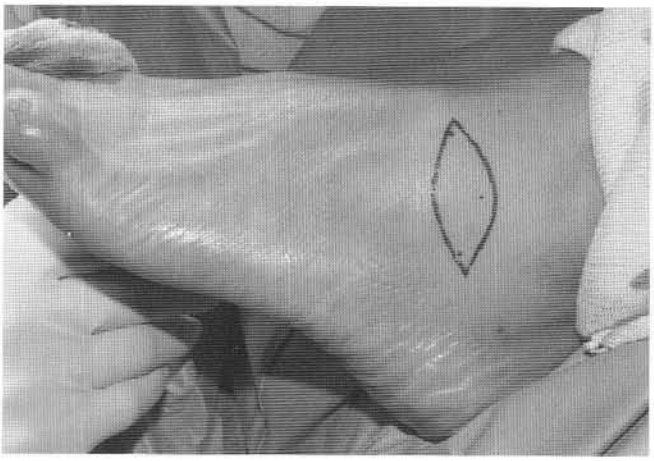

Figure 13. Outline for a FTSG obtained from the redundant skin over the sinus tarsi region of the foot. Relaxed skin tension lines are obeyed o prevent excessive tension and scarring in this region.

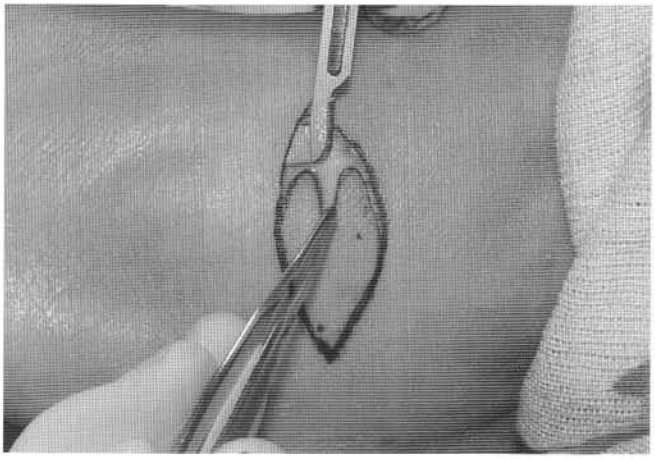

Figure 14. Incisions are made 90 degrees to the skin surface through the dermis to the subcutaneous tissue below. The graft is then gently freed from the underlying tissue.

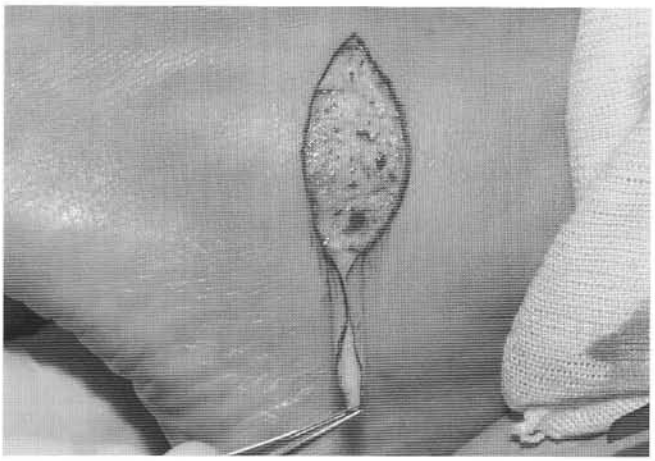

Figure 15. The full thickness skin graft is held gently with atraumatic forceps. The underlying tissue can be primarily repaired without significant undermining of the skin edges.

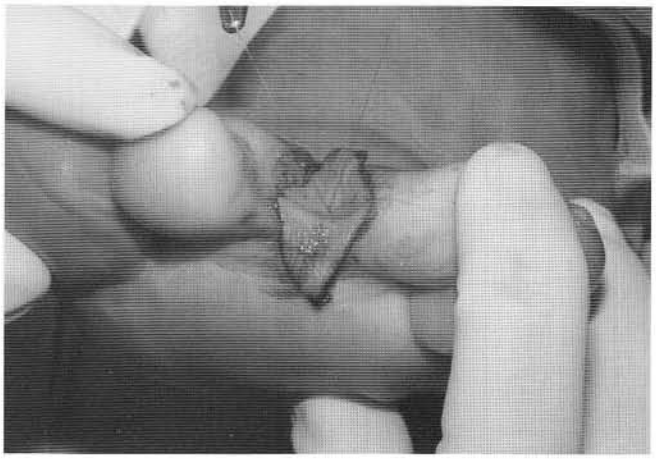

Figure 16. The graft is measured for size and excess graft is trimmed. Subcutaneous fat is removed from the dermis side of the graft. Suture is used to secure the graft in place. In this case, the corners are tagged to begin the suture process.

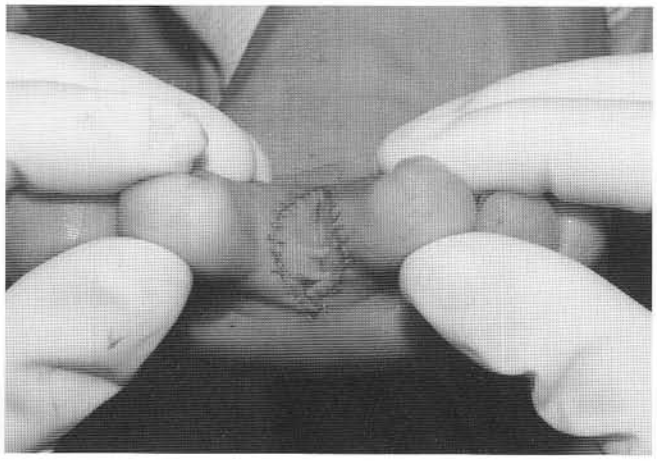

Figure 17. A running suture technique is utilized to secure the circumference of the graft in the same manner as for securing a split-thickness graft.

generally a result of interruption of this interface, either by mechanical movement (e.g., shearing forces) preventing diffusion, or rendering the graft non-permeable to penetration by small blood vessels (e.g., development of a fluid interface). Even small amounts of fluid (0.5 mm) can delay revascularization by 12 hours.[1] Stent dressings are often employed for the purpose of securing the graft in place with gentle even pressure across the graft, maintaining apposition of the graft to the underlying bed for diffusion of nutrients and to prevent hematoma or seroma formation.

Stent dressings provide the desired effect only if the surrounding tissues are mobile. A reliable method for securing a graft in place with gentle, even compression is to use saline- or mineral oil-saturated cotton balls that are wrung out until no longer compressible. These and additional layers of cotton are laid along the graft outline until an even plane is established with the surrounding wound edge. The entire dressing is then compressed equally with a conforming gauze dressing. Care should be taken to avoid excessive pressure on the dressing, as the ultimate viability of the graft is dependent on the formation of true vascular channels that can be compressed. This is especially important when the graft overlies an osseous prominence, such as the anterior tibia or malleolus.

For the first postoperative week, the limb is maintained elevated above the level of the heart to minimize tissue edema, and reduce the risk of hematoma and seroma formation. Room temperature should be kept above 75 degrees to protect the fragile dermal capillaries and encourage cutaneous blood flow. The graft may be inspected at daily intervals, however there is usually no need to completely remove the surgical dressings. This adds unnecessary trauma to the graft. Since true graft viability may not be known within the first 5 to 7 days, this regimen of strict non-weightbearing with limb elevation is instituted until certainty of graft take is established. Usually by the end of the first postoperative week the patient may dangle the limb at bedside for several hours daily and a gradual return to full dependency is carried out over the next two weeks.

GRAFT FAILURE

As discussed earlier, the most common reason for graft failure is hematoma or seroma formation within the graft/wound bed interface. This is prevented by adequate hemostasis prior to graft application and the use of slightly compressive dressings and strict extremity elevation after graft application. Intra-operatively hemostasis is established with manual pressure, dilute epinephrine, topical thrombin, limited electrocauterization or vessel ligation. Infection is the second most common cause of graft failure. The recipient bed must be free of infection prior to application, and appropriate systemic antibiotics must be instituted along with debridement in cases of osteomyelitis and deep wound coverage. Generally coverage is instituted for Staphylococcus species, Pseudomonas species, and Streptococcal species, although isolation of a specific organism should certainly guide the therapeutic regimen. Failure of graft survival may also be the result of inadequate vascularity to the region, a condition which should be dealt with prior to surgical reconstruction of any kind including skin coverage. Along with the presence or absence of clinical signs of peripheral vascular disease, lower extremity vascular indices, toe pressures, and transcutaneous oxygen levels are all helpful in this regard.

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