head of a pneumatic dermatome oscillates more rapidly than that of an electric dermatome, making harvesting smoother.[23]

The Davol-Simon skin graft dermatome is a relatively inexpensive dermatome powered by a rechargeable handle, similar to the handle of an electric toothbrush.[17,18] A disposable, nonadjustable cutting head harvests a split-thickness skin graft 33 mm (1½ inches) wide and 0.38 mm (0.015 inch) thick. Grafts obtained with this skin graft dermatome are too thin to impart a cosmetic appearance to wounds of horses, but they may be useful for covering relatively small wounds when cosmetic appearance is not important.

Although a power-driven dermatome provides precision harvesting, the widest graft that can be harvested with many power dermatomes is only 76 mm (3 inches). A surface firmer than the ventral aspect of the abdomen, the least conspicuous donor site on the horse, is often necessary when harvesting with a power-driven dermatome. Although operating a power-driven dermatome requires only a minimum of experience, a power-driven dermatome requires skilled maintenance.[8] Because of their expense, power-driven dermatomes are found primarily only at large equine surgical referral centers.

An advantage of the free-hand knife over the power-driven dermatome is that consistently uniform grafts more than 100 mm wide (4 inches or greater) can be harvested using a free-hand knife. Grafts can be harvested from the ventral aspect of the abdomen with a free-hand knife, which is a difficult feat for a power-driven dermatome. A free-hand knife is far less expensive than a power-driven dermatome, requires less maintenance, has fewer parts to malfunction, and is easier to sterilize and to transport.

Technique of Harvesting a Split-Thickness Graft

A split-thickness skin graft can be harvested from any convex surface of the body, but the cosmetic appearance of the horse should be considered when selecting a donor site, because a split-thickness graft of acceptable durability and hair coverage cannot be obtained without creating a large epithelial scar at the donor site. Harvesting a split-thickness skin graft is painful to the horse and can be accomplished only when the horse is anesthetized.

To harvest skin from the ventral aspect of the horse's abdomen using a free-hand knife, the horse is positioned in lateral recumbency with its abdomen protruding beyond the edge of the table. The ventral portion of the abdomen must protrude over the edge of the table to accommodate the handle of the hand-held knife. The donor site is prepared for aseptic surgery, but draping is not necessary. Harvesting usually begins at the umbilicus and extends craniad. The donor site can be stabilized, if necessary, by assistants stretching the skin with towel clamps. The knife is applied to the skin at an acute angle of about 5 to 10 degrees, and the skin is cut using a regular sawing motion, concentrating on moving the blade back and forth, rather than pushing it forward (Figure 25-11). Lubricating the donor site with physiologic saline solution and the blade with a light coating of mineral oil reduces friction. Mineral oil does not adversely affect acceptance of the graft.[8,18] Slight, uniform tension should be applied to the cut end of the graft as the graft is harvested.

After several centimeters of graft have been cut, the graft and donor site should be inspected to ensure that the graft is the desired thickness before harvesting is continued. The thickness

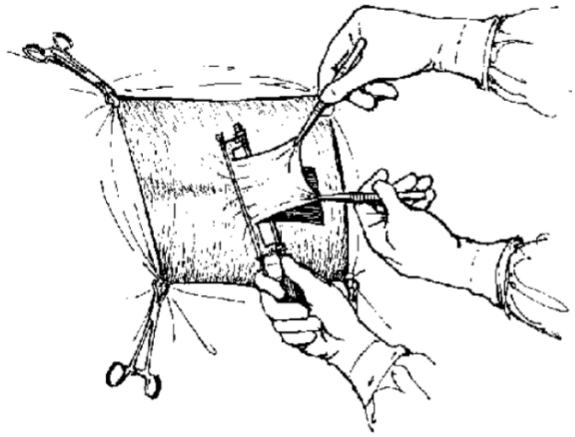

Figure 25-11. Harvesting split-thickness skin from the ventral aspect of the abdomen using a free-hand knife. The ventral portion of the abdomen must protrude over the edge of the table to accommodate the handle of the hand-held knife.

of the graft can be assessed subjectively by examining the graft for translucency and the donor site for the pattern of bleeding.[17,18] A shallow cut through the dermis produces a translucent graft and exposes many small bleeding vessels, whereas a deep cut produces a more opaque graft and exposes fewer but larger bleeding vessels. If subcutaneous fat is exposed, the graft is full-thickness and therefore much too thick. The depth of cut can be changed by repositioning the adjustable roller, by changing the pressure applied to the knife, or by raising or lowering the knife's angle of incidence. When the desired length of graft has been cut, the knife is tilted upward to sever the graft. If the graft is to be meshed and fully expanded, the length of graft should be considerably longer than the wound to which it is applied, because expanding the graft's width also shortens the graft's length.

The split-thickness graft is the most useful type of graft, because it can be used to cover defects too large to be covered by a full-thickness graft and because it survives more readily than does the full-thickness graft.[8,20,42,58] The cosmetic appearance of a wound healed by split-thickness skin grafting is inferior to that of a wound healed by full-thickness skin grafting, but it is superior to that of a wound healed by island grafting (see "Island Grafts," later). A split-thickness graft is less conveniently procured than a full-thickness graft because, to obtain a split-thickness graft, the horse must be anesthetized.

Meshing Sheet Grafts

A split-thickness or full-thickness sheet graft can be applied to a recipient bed as a solid or as a meshed sheet. A graft is meshed by uniformly fenestrating it manually with a scalpel blade or mechanically with a meshgraft dermatome. The primary reason for meshing a sheet graft is to allow the graft to uniformly cover a wound larger than the graft itself.[2,15,17,23,29,53,61-66] Grafts are also meshed to prevent serum, blood, or exudate from mechanically disrupting a newly applied graft from its delicate fibrinous and vascular attachments to the recipient bed. Fenestrations also enable a topically applied antimicrobial agent to contact a large

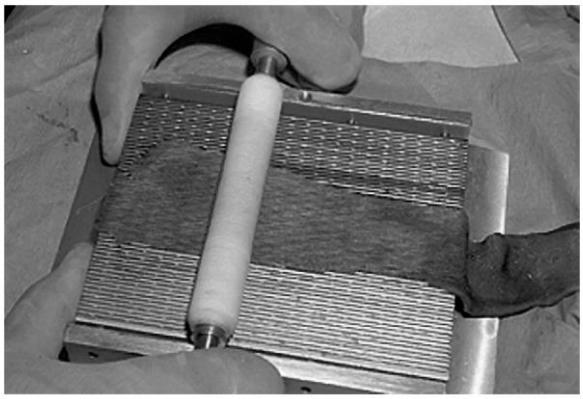

Figure 25-12. A Padgett mechanical skin mesher. The mesher consists of an aluminum block with staggered, parallel rows of blades and a Teflon rolling pin. The graft is positioned on the block, dermal side down, and pressed into the cutting blades with the rolling pin.

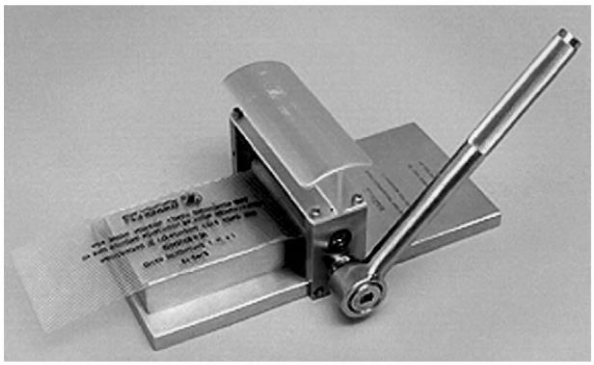

Figure 25-13. A Zimmer mechanical skin mesher. The mesher is capable of expanding the graft to many times its original area. The graft is positioned on a specially grooved plastic carrier, and the graft and carrier are fed through the mesh cutter by turning a hand crank.

Figure 25-14. An expanded, meshed graft on the back of a foal. The graft has the appearance of chain-link fencing and uniformly exposes portions of the wound within the fenestrations. These exposed portions of the wound must heal by contraction and epithelialization.

portion of the recipient wound. A meshed graft conforms to an irregular surface better than does a nonmeshed graft, and its ability to expand allows it to better tolerate motion. Fenestrations in the graft fill with fibrin, which increases the graft's stability on the recipient bed.[38]

An example of a meshgraft dermatome is the Padgett mechanical skin mesher (Mesh Skin Graft Expander, No. Z-PD-170). This instrument consists of an aluminum block with staggered, parallel rows of blades and a Teflon rolling pin. The graft is positioned on the block, dermal side down, and pressed into the cutting blades, in the direction of the blades, with the rolling pin (Figure 25-12). The rolling pin should first be rolled lightly across the graft to secure the graft to the blades of the mesher and then firmly so that the blades pierce the graft. The staggered cuts produce a meshed pattern that allows the graft to be expanded to three times its original width.

The Zimmer mechanical skin mesher (Zimmer Meshgraft Dermatome) is a more elaborate and expensive meshing instrument, capable of expanding the graft to one and one-half, three, six, or nine times its original area. The graft is positioned dermal side down on a specially grooved plastic carrier selected according to the degree of expansion desired, and the graft and carrier are fed through the mesh cutter by turning a hand crank (Figure 25-13). The pattern engraved onto the plastic carrier determines the distance between cuts. The graft must be placed on the ridged surface of the carrier, because placing the graft on the smooth side of the carrier causes the graft to be shredded into spaghetti-like strips.

An important consideration when purchasing a meshgraft dermatome is the width of grafts routinely harvested with the skin-graft dermatome. Grafts up to 100 mm wide are harvested routinely with a free-hand skin graft knife, but a graft wider than 76 mm is difficult to mesh with a Zimmer mechanical skin mesher. Grafts up to about 110 mm wide can be fitted onto the cutting surface of the Padgett mechanical skin mesher. Although the Padgett mechanical skin mesher accommodates a graft only 13.5 cm (5.3 inches) long, a longer graft can be meshed in sections.

Full-thickness sheet grafts of horses are difficult to mesh on commercial meshing instruments and often must be meshed manually. Meshing a graft manually is tedious, especially if the graft is large or if it must be greatly expanded. The skin is fixed to a cutting board, such as sterile sheet of cardboard or Styrofoam, with the dermal side up, and after the subcutaneous fascia is removed staggered, parallel rows of incisions are created using a scalpel blade. The longer and the more numerous the incisions, the greater the expansion.

An expanded, meshed graft has the appearance of chicken wire or chain-link fencing and uniformly exposes portions of the wound within the fenestrations (Figure 25-14). The amount of wound exposed within the fenestrations depends on the degree to which the graft is expanded. Portions of the wound covered by the graft heal primarily, but each portion of the wound exposed within the fenestrations must heal by contraction and epithelialization. The exposed portions of the wound epithelialize rapidly because of the enormous increase in the border of the graft from which epithelial cells migrate.[61,62] The epithelium that eventually covers the expanded fenestrations has no adnexa, causing the wound to heal with abundant, diamond-shaped epithelial scars. The more a graft is expanded at application, the more apparent are the diamond-shaped scars.[2,42,61,62] Greatly expanded grafts are difficult to apply, and

the greater the expansion, the longer the period of epithelialization. The size of the epithelial scars can be reduced by attaching the graft to the wound so that the fenestrations within the graft are parallel with the skin lines (i.e., parallel to the long axis of the limb).[63] The diamond-shaped epithelial scars within the grafted wound diminish in size as the grafted wound contracts.

Applying Sheet Grafts

Excess granulation tissue should be excised before the graft is harvested, to allow time for hemorrhage to stop before the graft is applied. Excising exuberant granulation tissue 24 hours in advance of grafting ensures hemostasis and provides time for budding capillaries to develop at the surface of the wound for rapid vascularization of the graft[47] (see "Preparation of the Recipient Site," earlier). If granulation tissue is not exuberant, the surface of the wound should be rubbed with a gauze sponge or gently scraped with a scalpel blade held 90 degrees to the wound, until serum exudes from the wound's surface.

The graft should be situated on the wound so that the direction of its hair growth conforms to that of the surrounding skin. A graft harvested with the horse anesthetized can be sutured or stapled to the wound's margin before the horse is allowed to recover from anesthesia. To avoid constant disturbance of the fibrin seal at the edge of the graft when securing the graft with sutures, the suture needle should pass from the graft to the surrounding skin, rather from the surrounding skin to the graft.[23] To suture or staple the graft to the wound's margin with the horse standing, the margin of the wound must first be desensitized using local or regional anesthesia. The graft can be fixed to the margin of the wound, with the horse standing, without using local or regional anesthesia, by overlapping and gluing the margin of the graft to the margin of the wound with cyanoacrylate glue (Superglue), provided that sufficient skin has been harvested to allow overlap of the graft (Figure 25-15). Applying the graft with the horse standing reduces the time of general anesthesia and eliminates the possibility of damage to the graft that may occur while the horse recovers from general anesthesia.

A graft need only be fixed to the wound's margin, because fibrin produced by the wound fixes the graft to the wound's surface within minutes after the graft is applied.[2,26] If the wound is large or is in an area that is difficult to immobilize, however, such as the dorsum of a fetlock, the graft can be further secured with simple interrupted sutures placed through the fenestrations in the meshed graft. To suture a graft to the bed of a fresh wound with the horse standing, the wound must first be desensitized with regional or local anesthesia. A graft can be sutured to granulation tissue with the horse standing without anesthesia because granulation tissue has no innervation (Figure 25-16). Sutures can be removed in 6 or 7 days when acceptance of the graft is certain. Catgut is convenient to use as a suture because it swells, causing the knot to loosen. If tied with a square knot, the suture can usually be removed by applying gentle traction to one end of the suture with a hemostat. Removing sutures in this fashion is easier than cutting the sutures.

Acceptance and Cosmesis

The thickness of a graft greatly influences its acceptance at the recipient wound.[8,17,20,23,27,28,58] The thinner the graft, the less

Figure 25-15. Attaching a graft to the margin of a wound, with the horse standing. The graft is attached by overlapping and attaching the margin of the graft to the margin of the wound with cyanoacrylate glue.

Figure 25-16. Suturing a graft to granulation tissue with the horse standing. Anesthesia is not necessary because granulation tissue has no innervation.

its metabolic demands and the less its demands for vascularity at the recipient bed. Blood vessels branch as they ascend the dermis, so the thinner the graft, the greater the number of exposed vessels. The greater the number of exposed vessels, the better the absorption of nutrients from the recipient wound and the more rapid revascularization from inosculation. The thinner the graft, the poorer its durability and cosmetic appearance.

Split-thickness grafts obtained from the hip, gaskin, or ventral aspect of the abdomen of horses that are 0.5 mm (0.020 inches) or less thick lack durability and have sparse or no hair coverage.[20] Split-thickness grafts harvested from these areas and from the ventrolateral aspect of the thorax that are between 0.63 mm (0.025 inches) and 0.76 mm (0.030 inch) thick have moderate to good piliation and good durability.[20,29] The thickness to which the graft should be harvested is a matter of judgment, because the thickness of the dermis varies between horses and between donor sites.[29] Although one of the aims of split-thickness grafting is to provide adequate piliation at both the donor and recipient sites, occasionally piliation is inadequate at either site.[56]

When donor skin is in short supply, such when a burn wound covers a large portion of the trunk, a "two-layer" technique of harvesting split-thickness grafts may provide sufficient skin to cover the wound. Using this technique, two thin split-thickness grafts are harvested from the same site. The first split-thickness graft is composed of the epidermis and a thin portion of the dermis. The second split-thickness graft, harvested from the same site, is composed only of dermis. Although the second is graft composed only of dermis, epithelialization proceeds from adnexa contained within to resurfaces the dermis.[67]

Island Grafts

An island graft is a small piece of full-thickness or split-thickness skin placed either into or onto a granulating wound.[68-70] Other names for this type of graft include implantation graft and seed graft.[3,4] Implanting island grafts into granulation tissue of horses, rather than applying them to the surface of the wound, avoids shearing forces between the graft and the bandage. The purpose of island grafting is to increase the area of epidermis from which epithelialization can proceed; consequently, wounds that receive island grafts heal primarily by epithelialization. Types of island grafts used to graft wounds of horses are the punch graft, the pinch graft, and the tunnel graft.

Punch Grafts

Punch grafts are small full-thickness plugs of skin that are harvested and implanted into granulation tissue using skin biopsy punches. Punch grafts can be taken directly from the horse or from an excised full-thickness sheet of skin.

Common donor sites for obtaining punch grafts directly from the horse are the ventrolateral aspect of the abdomen, the perineum, and the portion of the neck that lies beneath the mane. The donor site is clipped, scrubbed, and desensitized with a local anesthetic agent. The perineal area can be desensitized using caudal epidural anesthesia. Removing punch grafts directly from the horse with a skin biopsy punch creates small blemishes at the donor site (Figure 25-17). Therefore, the grafts should be harvested in a symmetrical pattern about 1 cm apart to improve cosmesis.[38] The small wounds created by the biopsy punch need not be closed, but suturing or stapling each wound may produce less-obvious blemishes.

Figure 25-17. Blemishes on a horse's neck created with a skin biopsy punch.

Subcutaneous fascia and fat should be sharply excised from each individual graft before it is implanted to facilitate plasmatic imbibition and re-vascularization.[71] Removing subcutaneous tissue from each small plug of skin is a tedious process. One method is to stretch the subcutaneous tissue between one thumb forceps grasping the top of the plug and another thumb forceps grasping the subcutaneous tissue. A second person excises the taut subcutaneous tissue from the dermis with scalpel blade. Another method is to excise subcutaneous tissue from the dermis while the cut disc remains attached to the horse. The biopsy punch is rotated until it penetrates the skin, and the graft is elevated, using thumb tissue forceps, to expose the attached subcutaneous tissue, which is excised from the dermis using a scalpel blade.[72]

Punch grafts can also be harvested from an elliptical, full-thickness sheet of skin, which is usually harvested from the cranial pectoral area, where the skin is relatively mobile.[1] A 10-cm–long by 4-cm–wide (4-inches–long by 1½-inches–wide) section of skin provides enough punch grafts to cover most wounds and allows easy primary closure of the donor site.[54] The section of skin is stretched and secured, epidermal side down, to a sterile piece of cardboard or Styrofoam or to a sterile polypropylene block. After all subcutaneous tissue is sharply excised from the section of skin, full-thickness plugs are cut from the skin using a 6- to 7-mm–diameter skin biopsy punch (Figure 25-18). The grafts are stored on a gauze sponge moistened with physiologic saline solution until they are implanted, and the wound created at the donor site is closed in one or two layers. Applying a stent bandage to the sutured wound decreases tension on the suture line.

Exuberant granulation tissue at the recipient site should be excised to the level of the margin of the wound 24 to 48 hours prior to grafting. The recipient holes in the granulation tissue should be created before the grafts are harvested to allow hemostasis to occur prior to implantation. The depth of the recipient holes should correspond to the thickness of the grafts to be inserted.[1] To avoid obscuring the wound with hemorrhage that occurs when the recipient holes are created, creation of the recipient holes should begin at the distal end and proceed proximad.[71] A cotton-tipped applicator inserted into

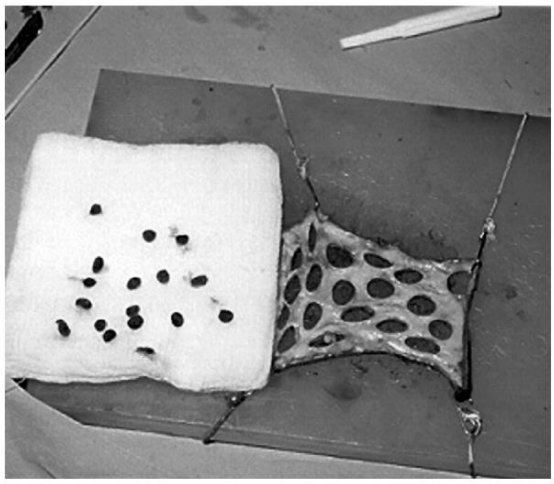

Figure 25-18. Punch grafts harvested from a full-thickness section of skin. The section of skin was obtained from the pectoral region. Full-thickness plugs are cut from the skin using a skin biopsy punch.

Figure 25-19. Cotton-tipped applicators inserted into recipient holes in a granulating wound. An applicator enables a hole to be located easily and prevents a blood clot from forming in the hole.

the recipient holes enables each hole to be located easily for insertion of a graft and prevents a blood clot from forming in the hole (Figure 25-19). Spraying the wound with phenylephrine before creating the recipient holes may improve visibility by decreasing hemorrhage. Creating the recipient holes hours in advance of implantation ensures a hemorrhage-free wound for grafting.[54] The holes should be placed about 6 mm (about ¼ inch) apart in a symmetrical pattern.[1]

The recipient holes are created with a slightly smaller biopsy punch than that used to harvest the grafts, to allow for contraction of the graft. For example, if the grafts are harvested with a 7-mm–diameter biopsy punch, the recipient holes should be

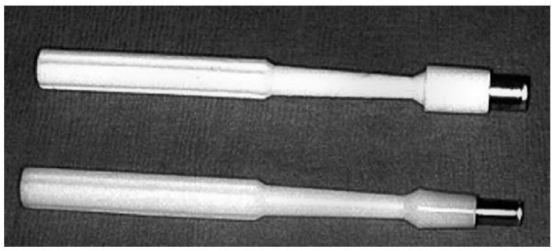

Figure 25-20. Skin biopsy punches used for harvesting punch grafts and for creating recipient holes. The recipient holes for punch grafts are created with a slightly smaller skin biopsy punch than that used to harvest the grafts. The larger punch is used to harvest punch grafts, and the smaller biopsy punch is used to create recipient holes.

created with a 5-mm biopsy punch (Figure 25-20). The grafts are inserted into recipient holes, and the grafted wound is covered with a non-adherent dressing and a bandage. Consideration can be given to the direction of the hair growth on the graft when the graft is inserted, but the cosmetic outcome may be little affected by properly orienting the direction of the hair.

The pigmented, superficial portions of the grafts frequently slough, exposing non-pigmented deeper layers. By 3 weeks, each plug of skin is surrounded by a red ring, which represents migrating epithelium.[1] Acceptance of the grafts is ensured if the grafts remain within the recipient hole.[38] Survival of 60% to 75% of the grafts is a realistic expectation.[54] The time required for the wound to completely epithelialize is inversely proportional to the amount of wound covered by viable plugs. Punch grafting requires no expensive or sophisticated equipment and little expertise, and the grafts are accepted into recipient beds that are unsuitable for sheet grafting.[1] Punch grafting can be performed with the horse standing, making this an inexpensive method of grafting wounds. Punch grafting is usually reserved for small wounds where cosmesis is not important. Wounds healed by punch grafting are covered primarily by an epithelial scar from which grow sparse tufts of divergent hair (Figure 25-21).

Pinch Grafts

Pinch grafts are small discs of skin, harvested by excising an elevated cone of skin, that are laid onto or implanted into granulation tissue.[26,49,55,68-70] The pinch graft is sometime referred to as a Reverdin graft.[70] The donor sites for obtaining pinch grafts from the horse are the same as described for punch grafts; small blemishes created at these donor sites are relatively inconspicuous. A disc of optimal size is approximately 3 mm in diameter, which approaches full thickness toward its center, but its thickness diminishes toward its periphery.[69]

Preparation of the donor site is identical to that described for punch grafts. A cone of skin is elevated using a tissue forceps, a suture needle, or a hypodermic needle with a bent point, and it is excised with a scalpel blade (Figure 25-22).[49,55,68-70] A No. 11 scalpel blade is most suited for excising the cone of skin. The grafts are stored on a gauze sponge moistened with physiologic saline solution until they are implanted.

The recipient site is prepared in the same way as for punch grafts. The recipient pockets can be created hours in advance of implantation to ensure a hemorrhage-free wound for grafting,

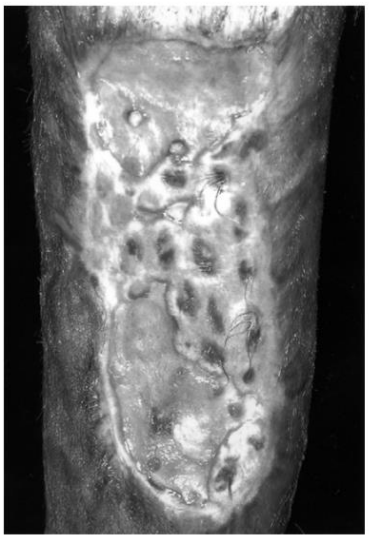

Figure 25-21. A nearly healed, punch-grafted wound. The nonpigmented tissue between the pigmented punch grafts is epithelium. This epithelium will eventually become pigmented.

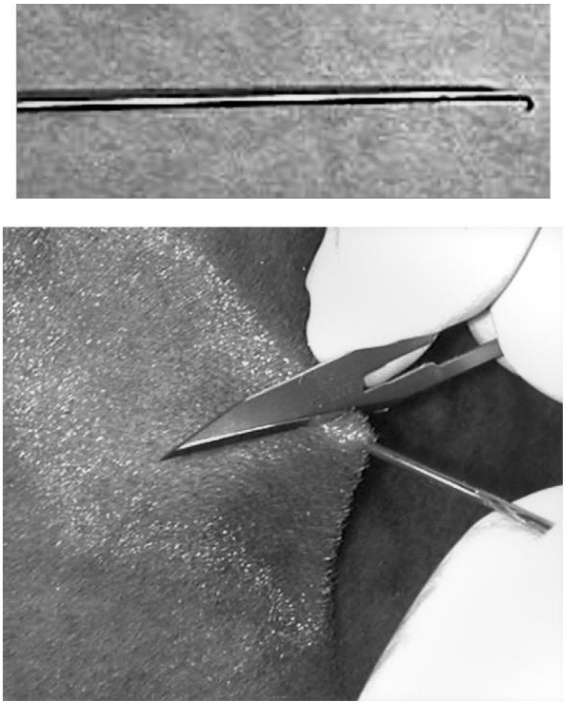

Figure 25-22. Harvesting a pinch graft. A cone of skin is elevated using a hypodermic needle with a bent point, and the elevated cone of skin is excised with a scalpel blade.

Figure 25-23. A wound covered with pinch grafts.

but locating the pockets after hemorrhage has ceased may be difficult.

To implant a graft, a No. 15 scalpel blade is stabbed into the granulation tissue of the recipient bed at an acute angle to create a shallow pocket into which the graft is inserted. Implantation should begin at the distal end and proceed proximad, because the pockets are obscured by hemorrhage after they are created. The grafts should be implanted about 3 to 5 mm apart.[69] Each graft is laid onto the wound, epidermal side up, proximal to the pocket, and slid into the pocket using a hypodermic needle, a straight suture needle, or the scalpel blade used to create the pocket. Consideration can be given to the direction of the hair growth on the graft when the graft is inserted, but the cosmetic outcome is little affected by properly orienting the direction of the hair. To speed implantation, three or more grafts can be laid onto the granulation tissue at once, each 15 to 20 mm (6 to 8 inches) proximal to its proposed site of implantation. Hydrostatic pressure prevents the grafts from falling from the wound. The surgeon creates a pocket distal to a graft and inserts the graft into the pocket using the same scalpel blade that was used to create the pocket. The surgeon can create and implant the pockets in rapid succession without looking away from the wound.

Wounds created at the donor site are left to heal by second intention or closed with a single suture or staple. The grafted wound is covered with a nonadherent dressing and a bandage.

The thin layer of granulation tissue covering each pinch graft usually sloughs between the first and second week after grafting.[69] Grafts initially appear as dark spots on the wound's surface (Figure 25-23), but frequently the superficial pigmented portion of the graft sloughs, causing the graft to appear as a white spot surrounded by pink granulation tissue. Within 3 weeks, each disc of skin is surrounded by a red ring, which represents migrating epithelium. Epithelium migrates from the margin of the wound, as well as from the margin of each graft, so that eventually the entire wound is covered with epithelium. Even under adverse conditions, one can expect at least 50% to 75% of the grafts to survive.[69]

Pinch grafting, like punch grafting, is a relatively inexpensive technique of grafting, because the procedure can be performed with the horse standing and because only basic instruments are required. Little expertise is necessary, and the grafts can survive in a granulation bed that is less than ideal.[3,68] Pinch grafting is tedious, however, and imparts a poor cosmetic appearance, because the wound is left covered by an epithelial scar from which grow sparse tufts of divergent hair.

Tunnel Grafts

Tunnel grafts are strips of split-thickness or full-thickness skin implanted into tunnels created in granulation tissue.[4,73,74] The grafts are exposed days later, when they have re-vascularized, by excising the overlying granulation tissue that forms the roof of the tunnel. Donor skin can be harvested from various sites on the horse, using various techniques, and implanted with the horse anesthetized or sedated.

Split-thickness or full-thickness strips of skin can be harvested conveniently from the portion of the neck that lies beneath the mane or the ventral aspect of the flank.[4,73,74] In preparation for harvesting strips of skin, linear wheals, 2 to 3 cm wide and slightly longer than the wound to be grafted, are created along the longitudinal axis of the donor site by subcutaneously injecting local anesthetic solution (or physiologic saline solution if the graft is to be harvested with the horse anesthetized).

A straight intestinal forceps is applied to the base of each wheal so that skin protrudes slightly above the jaws of the forceps.[4,73,74] If a strip of skin longer than the jaws of the forceps is required, two intestinal forceps are applied end-to-end to the base of the wheal. The thickness and width of the graft is determined by the amount of skin that protrudes above the jaws. The protruding skin is severed with a scalpel (Figure 25-24). If the excised strip of skin is full thickness, subcutaneous tissue should be removed from it to expose the dermis, and the wound at the donor site should be closed with staples or sutures. If the strip of skin is split thickness, the donor site can be closed or left open.

Full-thickness strips of skin can also be harvested from the neck or ventral portion of the abdomen by making a series of parallel incisions 2 mm apart.[74] Strips are excised, and subcutaneous tissue attached to the dermis is sharply excised. The donor sites are closed with sutures or staples. Split-thickness strips of skin can be cut from a split-thickness sheet of skin usually harvested from the ventral aspect of the abdomen or ventrolateral aspect of the thorax, using techniques previously described (see "Technique of Harvesting a Graft," earlier). The donor site of the split-thickness sheet graft heals by epithelialization.

To implant a strip of skin in the granulation bed, the end of a long, thin, rat-tooth alligator forceps is inserted into granulation tissue at the edge of the wound and advanced through the granulation tissue at a depth of about 5 or 6 mm until it emerges at the opposite margin of the wound.[4,74] One end of the graft is grasped in the jaws of the forceps, with the epidermis positioned toward the surface of the wound, and pulled through the tunnel. The grafts should be embedded at right angles to the convex surface of the wound to aid entry and exit of the forceps.[74] A wound that is not convex is more easily grafted if granulation tissue is allowed to proliferate so that it protrudes slightly above the margin of the wound.[4] The strips should be embedded about 2 cm apart.[74]

The strip of skin is embedded in two steps if the alligator forceps is not long enough to completely span the wound, or if the wound is too convex for the alligator forceps to completely span it.[4,73,74] In either case, the forceps is advanced through the granulation tissue as far as possible and exited, one end of the graft is grasped, and the forceps is pulled back through the tunnel, with the graft in tow (Figure 25-25). The

Figure 25-24. Harvesting a tunnel graft. One or two straight intestinal forceps are applied to the skin, so that skin protrudes slightly above the jaws of the forceps. The protruding skin is severed with a scalpel.

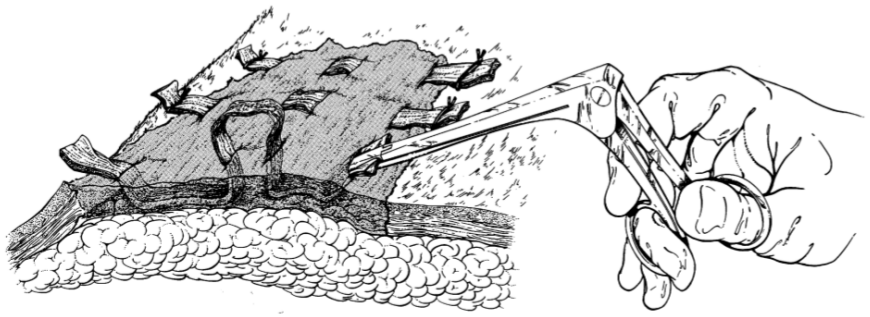

Figure 25-25. Implanting a tunnel graft using an alligator forceps. The strip of skin is embedded in two steps if the forceps is not long enough to completely span the wound.

end of the forceps is reinserted into the granulation bed at the opposite margin of the wound and advanced beneath the surface of the granulation tissue until it emerges at the site of exit of the graft. The end of the graft is grasped in the jaws of the forceps, and the forceps, with graft in tow, is pulled back through the second tunnel.

The graft can also be embedded by positioning the strip of skin onto a strip of adhesive tape, with the epidermis next to the tape.[73] The purpose of the adhesive tape is to prevent the edges of the strip from folding inward and to act as a guide when the grafts are later exposed. The tape should extend 5 cm beyond one end of the strip, and excess tape at this end is folded over the skin so that about 1 cm of the end of the strip is covered by tape. Excess tape along the graft's margin is trimmed with scissors. The tape-covered end of the graft is fitted through the eye of a 10- to 12-cm (4- to 5-inch) cutting needle with a flat curve, and the graft–tape composite is implanted by advancing the needle beneath the surface of the granulation bed. If the needle is not long enough to span the wound completely, or if the wound is too convex for the needle to completely span it, the needle is advanced beneath the bed as far as possible, exited, and reentered at the point of exit for a second bite. Another method of creating the strips of graft and tape is to lay a sheet of split- or full-thickness skin, epidermal side down, onto the sticky side of a similarly sized sheet of adhesive tape; strips of skin and tape are cut from this composite.[54]

The exposed ends of the embedded strips are attached to the margin of the wound with a suture, staple, or cyanoacrylate glue, and the wound is covered with a non-adherent dressing and a pressure wrap. Six to 10 days after grafting, the roof of each tunnel is removed, with the horse sedated or anesthetized, to expose the grafts, and if necessary, to remove adhesive tape.[4,73,74]

To remove the roof of a tunnel, a smooth, malleable probe is inserted into the tunnel superficial to the graft, and a V-shaped strip of granulation tissue is carefully excised over the probe with a scalpel blade to expose the graft. The roof of each tunnel can also be sawed off using a twisted doubled piece of fine wire threaded through the tunnel.[73] Accidentally removing a graft while attempting to expose it or failure to locate buried grafts can detract from the success of tunnel grafting.[74] These complications can best be avoided by applying a tourniquet proximal to the wound to enhance visibility or by exposing the grafts with the horse anesthetized. Placing the grafts closer than 2 cm apart may affect the viability of granulation tissue surrounding the grafts. About 60% to 80% acceptance of the strips can be expected.[73,74]

Tunnel grafting is recommended primarily for wounds located in areas where immobilizing other types of grafts would be difficult, such as the dorsal aspect of the hock.[73,74] Tunnel grafts are unaffected by movement in highly mobile areas, because the grafts are circumferentially encompassed and immobilized by granulation tissue. Tunnel grafting does not require expensive equipment and can be performed with the horse standing, but the technique requires the presence of a granulation bed, and aspects of this technique, especially removing the top of the tunnels, make tunnel grafting relatively tedious. The tedious job of removing the granulation tissue over the graft may not be necessary; however, if the graft is embedded so that only 1 to 1.5 mm of granulation tissue covers the graft. The shallow covering of granulation tissue sloughs, usually within a week, exposing the graft.

Modified Meek Grafting Technique

The modified Meek technique of skin grafting is a combination of island grafting and split-thickness sheet grafting.[30] Using this technique, 3-mm^2 islands of split-thickness skin, or micrografts, are applied to the surface of the wound. The technique is particularly useful for grafting large wounds because the donor skin can be expanded more with micrografts than with meshed sheet grafts.[75] This technique of grafting is particularly useful when the donor skin is in short supply, as may be the case for horses with extensive burns.

Meek micrografting equipment consists of a frame, a cutting block, and a pneumatic or hand-driven motor. A split-thickness section of skin of the desired thickness is harvested with the horse anesthetized (see "Split-Thickness Sheet Grafting," earlier) and the split-thickness graft is placed, dermal side down, onto a 42 × 42 mm cork plate and trimmed to the size of the plate. The cork plate, containing the graft, is placed onto a cork holder, which is placed in a cutting block (Figure 25-26). The cork, covered with graft, is then passed through a machine that contains 13 rotating, circular blades that cut the graft, but not the cork, into 14 3-mm wide strips (Figure 25-27). The cork and

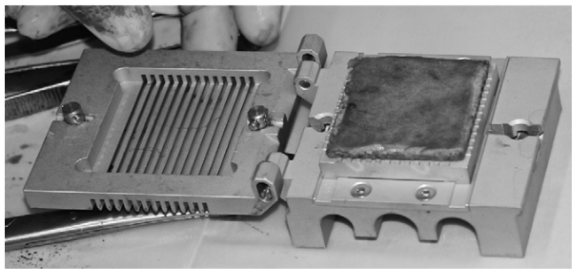

Figure 25-26. To obtain Meek micrografts, a split-thickness graft is placed with the dermal side down, on a cork template and trimmed exactly to fit the template. The cork template with graft is placed on a cork holder, which is then placed in the cutting block. (Courtesy Jacintha Wilmink, Woumarec, Wageningen, NL.)

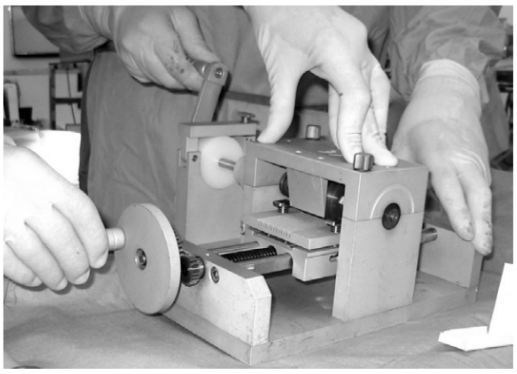

Figure 25-27. A Meek micrograft machine shown with a hand-drive (a machine with pneumatic motor for turning the knives is also available). The cutting block with the cork template and graft are passed through the Meek micrograft machine, which contains 13 circular knives that cut the graft into 14 3-mm wide strips. The cork holder is rotated 90 degrees and replaced onto the cutting block, and by passing it through the machine again, the strips of graft are cut into 196 (14 × 14) 3 × 3 mm micrografts. (Courtesy Jacintha Wilmink, Woumarec, Wageningen, NL.)

graft are rotated 90 degrees, replaced onto the cutting block, and again passed through the machine, which cuts the strips of graft into 196 (14 × 14) 3 × 3 mm grafts.

The epidermal surface of the graft is sprayed with an adhesive, which is allowed to dry until it becomes tacky. The cork plate, covered with graft, is pressed onto a pleated polyamide gauze backed by aluminum foil, which when unfolded expands the graft in a ratio of 1:3, 1:4, 1:6, or 1:9 (Figure 25-28). A pleated gauze with the smallest expansion ratio (1:3) is used for grafting most wounds of horses because most horses have an abundant amount of skin available for harvesting. The cork is carefully removed, leaving the postage stamp–sized islands of graft on the gauze. The pleats are unfolded, separating the grafts at a set uniform distance, by applying traction to all of its four sides (see Figure 25-28), and the supporting aluminum backing is peeled off and discarded, leaving the expanded gauze with the separated islands of graft. The expanded gauze to which the grafts are attached is trimmed appropriately, applied graft side down to the wound, and secured to the margin of the wound with staples or sutures (Figure 25-29). The grafted wound is covered with a bandage or a cast. The gauze can be removed after about 6 days, when the grafts have become attached to the wound.

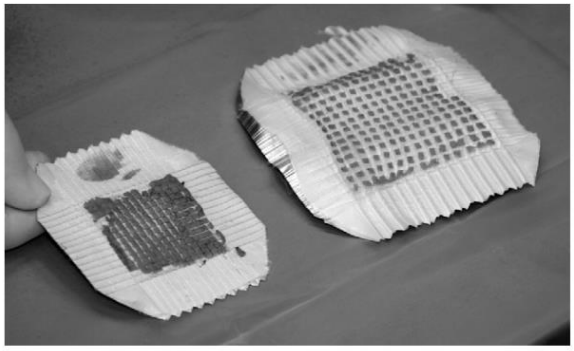

Figure 25-28. *Left,* The epidermal side of the Meek micrografts was sprayed with an adhesive, and the graft was glued to a prefolded pleated polyamide gauze (e.g., plissé), after which the cork template was removed. *Right,* The plissé was unfolded in two directions, separating the Meek micrografts at set uniform distances. (Courtesy Jacintha Wilmink, Woumarec, Wageningen, NL.)

Figure 25-29. A, A large chronic wound at the time of admission. The horse was caught in a fence several weeks earlier and acquired a large loose skin flap on the medial side of the metatarsus; **B,** One month later grafting was performed on the prepared wound. The expanded gauze with Meek micrografts was applied to the wound, and the gauze was trimmed to the size of the wound and secured with staples and sutures. The loose skin flap that was retracted was mobilized and secured with three big sutures to the lateral wound margin; **C,** The same horse 1 month later. Nearly all micrografts are accepted, and the wound is almost healed. (Courtesy Jacintha Wilmink, Woumarec, Wageningen, NL.)

Figure 25-30. A, A nonhealing wound on the palmar aspect of a metatarsus is almost healed after receiving Meek micrografts 24 days earlier. The original square Meek micrografts from which epithelialization proceeds can still be seen. Only tiny areas remain to be epithelialized. **B,** Five months after grafting, the grafted site is covered with hair the same color as that at the donor site. The hair coat is somewhat sparser than the surroundings because the newly formed epithelium between the micrografts does not produce hair. (Courtesy Jacintha Wilmink, Woumarec, Wageningen, NL.)

As the wound contracts, the distance between the grafts decreases. Most wounds that receive Meek micrografts are healed within a month, regardless of the wound's size and location.[30] Hair growth is regular, but thinner and longer than normal (Figure 25-30).

The modified Meek technique of skin grafting provides uniform distribution of properly oriented islands of split-thickness skin. Detachment of one Meek micrograft, such as from infection or movement has no direct effect on surrounding micrografts because the micrografts are not connected to each other. Detachment of a portion of a sheet graft, on the other hand, may propagate into other areas of the graft, resulting in complete loss of the graft.[30,75,76] Meek micrografts are, therefore, more easily accepted by poor-quality wounds than are sheet grafts and can be applied with greater ease and in a higher concentration than can other types of island grafts, such as pinch, punch, or tunnel grafts. Acceptance of Meek micrografts in horses appears to be consistently better than what can be achieved using other techniques of skin grafting, and in one study, acceptance approached 95%.[30]

A disadvantage of the modified Meek micrografting technique over other methods of island grafting is that the horse must be anesthetized to harvest the split-thickness donor skin. Equipment to harvest the split-thickness skin and the micrografting machine are relatively expensive but no more so than much of the mechanized equipment available for harvesting and meshing sheet grafts.

AFTERCARE OF THE DONOR SITE

The donor site of a split-thickness graft retains a portion of the dermis and is comparable to a deep abrasion.[15,18,29] Blood and fibrin form a scab over the abrasion, and beneath this scab, epithelial cells from the wound's edge and epithelial cells produced by adnexa in the remaining dermis migrate to cover the surface of the abrasion. The wound at the donor site is usually covered by epithelium within 1 to 3 weeks, depending on the depth of the cut (Figure 25-31).[20,62] The new pink epithelium covering the donor site begins to develop pigment within a month after it forms, causing the epithelial scar to become black. The quantity of adnexa is greatest in the upper layers of the dermis, and consequently, healing of the donor site proceeds more quickly when a thin skin graft is harvested.[15,20] When grafts between 0.63 mm and 0.76 mm thick are harvested from the horse, the donor site heals with a noticeable epithelial scar.[20,61]

Figure 25-31. The donor site of a split-thickness graft 2 weeks after the graft was harvested. The donor site is nearly covered by epithelium. The new, pink epithelium will begin to develop pigment within a month, causing the epithelial scar to become black.

Pain caused by exposure of nerves at the donor site of a split-thickness graft can be reduced by bandaging the donor site,[15] but split-thickness grafts of horses are virtually always taken from an area that is difficult to bandage. Pain can be decreased by covering the donor site with fine-mesh gauze or a biological bandage, such as a stored allograft or xenograft (see "Allografts and Xenografts" and "Storage of Grafts," later). The gauze or biological bandage falls off when the donor site is completely

epithelialized. An uncovered donor site develops a scab, and this scab should not be removed. Any attempt to remove the scab is met with violent resistance from the horse, and its removal interferes with epithelialization that proceeds beneath it. An analgesic drug, such as phenylbutazone, should be administered before the graft is harvested and for at least several days after surgery.

AFTERCARE OF THE RECIPIENT SITE

The grafted wound should be covered with a sterile, nonadherent dressing, such as cotton nonadherent film dressing (Telfa Sterile Pads), rayon polyethylene dressing (Release), or petrolatum-impregnated gauze dressing (Adaptic). Petrolatum-impregnated gauze dressings can be prepared by steam-autoclaving a container filled with gauze sponges topped with a dollop of petrolatum. The petroleum impregnates the gauze as it melts. The wide weave of a gauze sponge, however, makes the sponge more likely to adhere to the grafted wound than would a commercially available petrolatum-impregnated gauze dressing with a close weave.

The primary dressing is secured to the grafted wound with sterile elastic, conforming, rolled gauze. If the grafted wound is in an area that is difficult to immobilize, such as the dorsal aspect of the hock, securing the primary dressing with staples[38] or with elastic adhesive tape, rather than rolled gauze, may help to decrease shearing forces between the graft and the bandage. The secondary layer of the bandage should be bulky, to decrease motion of the limb, and absorbent, to wick bacteria and destructive enzymes from the grafted wound. Immobilizing the limb with a cast is usually not necessary unless the grafted wound is located in a highly mobile area, such as the dorsum of the fetlock. A splint or a Robert Jones bandage applied to the limb usually immobilizes the grafted wound sufficiently.

The bandage should not be changed for 4 or 5 days after grafting, unless virulent nosocomial infections are a common problem in the hospital, because changing the bandage may disturb the graft's delicate attachment to the wound. If such infections are a common problem in the hospital, however, the bandage should be changed daily, or even twice daily, for at least 5 days. Changing the bandage daily allows exudate, which contains destructive enzymes, to be removed from the wound, and it allows application of an appropriate antimicrobial drug to the wound. Complete loss of a sheet graft, from infection or motion, later than 5 days after grafting is uncommon.[38] Streptococci or pseudomonads can quickly destroy a recently applied graft (Figure 25-32), so prompt recognition of infection and application of an appropriate antimicrobial drug to the grafted wound are necessary. Infection caused by a *Pseudomonas* species is characterized by the presence a bluish-green exudate on the surface of the wound and an odor similar to that of grape juice. Exudate that develops on a grafted wound should be cultured for bacterial growth, and isolates should be tested for antimicrobial susceptibility. Until the results are known, a broad-spectrum antimicrobial agent, effective against both β-hemolytic streptococcus and *Pseudomonas,* such as a combination of ticarcillin disodium and clavulanate potassium,[50] should be applied topically to the wound.

If the limb has been immobilized in a cast, and if nosocomial infection from streptococci or pseudomonads is a common problem in the hospital, an antimicrobial drug should be applied periodically to the wound through an infusion tube fixed to the grafted wound and exited through the top of the cast. A serviceable infusion tube can be prepared from silicone tubing by sealing its distal end and perforating it (with a 25-gauge needle) in multiple places along the portion that lies adjacent to the wound.

Figure 25-32. A recently applied graft destroyed by streptococcal infection.

Even a docile horse should be heavily sedated during the initial bandage changes to help avoid movement that may disturb the delicate vascular connections forming between the recipient bed and the graft. Adherence of the primary dressing to the grafted wound by fibrin that exudes through a meshed graft usually indicates that the graft is well adhered to the wound by a fibrin seal. Soaking the primary dressing with physiologic saline solution may ease removal of the dressing. The dressing should be removed by grasping it at one end and pulling it parallel to the wound; pulling the dressing perpendicular to the wound places more traction on the graft. If the primary dressing cannot be removed easily, it should be left in place.

Exuberant granulation tissue that inhibits epithelial migration may grow through the latticework of a meshed graft, especially if the graft was applied to the wound fully expanded. A corticosteroid applied to the grafted wound causes the exuberant granulation tissue within the graft to regress, allowing epithelial migration to proceed, even if at a slower than normal pace.[29,77-79]

Ideally, grafted wounds on limbs should be protected by a bandage until epithelialization is complete. If bandaging becomes impractical before epithelialization is complete, small, nonepithelialized areas within the grafted wound can be allowed to heal beneath a scab, which soon forms when the wound is left exposed.

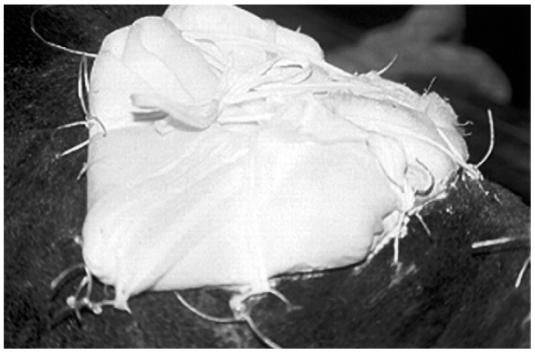

Figure 25-33. A stent bandage applied to a grafted wound on the back of a horse. A grafted wound in an area that is difficult to wrap can be protected with a stent bandage. To apply a stent bandage, the grafted wound is covered with a nonadherent dressing followed by a bolus of gauze. Long ends of interrupted sutures, preplaced around the margin of the grafted wound, are tied tightly over the bolus.

A grafted wound in an area that is difficult to wrap, such as the abdomen or thorax, can be protected with a "tie-over" bolus dressing, sometimes referred to as a stent bandage.[4,29,71] To apply a stent bandage, the grafted wound is covered with a nonadherent dressing followed by a bolus of gauze. Long ends of interrupted sutures, preplaced around the margin of the grafted wound, are tied tightly over the bolus (Figure 25-33).

Pressure on a graft from a bandage is not necessary for the graft to be accepted, so, for areas that are difficult to bandage or for wounds that are chronically plagued with infection, the grafted wound can be left uncovered.[2,23] "Open" grafting avoids shearing forces imposed by a bandage and avoids maceration of the graft by allowing constant drainage of exudate. To successfully employ open grafting, precautions, such as tying the horse or applying a neck cradle, must be taken to prevent the horse from disturbing the exposed graft.

Some horses probably suffer from hyperesthesia at the grafted wound, so when bandaging is discontinued, temporarily applying a neck cradle or tying the horse may be prudent to prevent the horse from mutilating its grafted wound. Drying and scaling of the healed donor and recipient sites of a split-thickness graft, caused by reduced concentration of eccrine glands, can be lessened by periodically applying an ointment containing lanolin until enough glands regenerate that scaling is no longer a problem.[8]

ALLOGRAFTS AND XENOGRAFTS

Cutaneous allografts (i.e., skin grafts taken from one animal and transplanted to another of the same species) or cutaneous xenografts (i.e., skin grafts taken from one animal and transplanted to another of a different species) can be used as a biological dressing on wounds of horses. Cutaneous allografts and xenografts, usually pigskin, have been used extensively since the middle of the 19th century to temporarily dress large wounds on humans. Although xenografts have been used to dress wounds of horses,[12,13,80,81] the use of cadaveric, cutaneous allografts to dress their wounds has only recently been investigated.[14] Viable cutaneous allografts can be obtained from refrigerated cadavers 24 hours or longer after death.[82] Allografts applied to wounds of horses seem to survive between 2 and 3 weeks, but the length of survival can be difficult to determine, because even when the superficial portion of the graft appears to be desiccated, the deeper portion of the graft may still be viable and attached to the recipient wound by strong vascular connections.

A cutaneous allograft or xenograft can be used to temporarily cover a wound if autografting is physically unfeasible or economically impractical. An allograft or xenograft encourages healing by promoting epithelialization and angiogenesis at the recipient bed.[83] The allograft or xenograft also retards formation of exuberant granulation tissue and acts as a bacterial barrier to protect the wound from infection.[12,80,82] A cutaneous allograft or xenograft revascularizes, and this vascularization may explain, at least in part, the ability of the cutaneous allograft or xenograft to resist infection.[11] Acceptance of a graft is not essential for bacterial destruction, however, because bacterial colonization decreases even beneath nonviable grafts, perhaps because the fibrin that forms between the graft and the wound enhances phagocytosis.[12,13,15,39,84] Adherence of an allograft or xenograft to a wound is a useful indicator that the wound is sufficiently healthy to accept an autograft.

The use of cutaneous porcine xenografting in humans arose from the need for a substitute for allografts as a biological dressing because of the short supply of cadaveric skin, but clinical comparisons in humans have shown that cutaneous porcine xenografts are inferior to cutaneous allografts.[11] Cutaneous porcine xenografts are more poorly adhered than allografts, allow higher bacterial counts in the wound, and cause a more intense immunological rejection.

STORAGE OF GRAFTS

Autografts or allografts can be applied successfully to wounds after being stored for several weeks at refrigeration temperature, in gauze that has been soaked in either physiologic saline solution or lactated Ringer's solution.[8,17,23] Skin can be stored in a refrigerator in a nutrient medium, such as McCoy's 5A Medium to which serum has been added, for much longer periods.[82,85-87]

McCoy's 5A Medium is a tissue-culture medium composed of a balanced electrolyte solution to which amino acids, vitamins, dextrose, and a pH indicator (phenol red) have been added. Adding vitamins, amino acids, dextrose, and serum to the electrolyte solution greatly extends the time that a graft can be stored. Skin from humans has been stored successfully in refrigerated nutrient media for 6 to 8 weeks.[82,85] Wounds of horses have been grafted using split-thickness skin grafts refrigerated at 4° C in a solution of McCoy's 5A Medium and horse serum for 3 weeks, with consistently successful results,[87] and wounds of some horses have been grafted successfully using skin stored for as long as 12 weeks.

The concentration of serum in the storage medium should be between 10% and 33%.[88] A concentration of serum greater than 33% stimulates the metabolic activity of the graft. Antigenic reaction of the serum to the graft is avoided by using a commercially available antibody-free serum (GG-Free Horse Serum), pooled homologous serum, or the horse's own serum.[85] The stored grafts should be allowed access to air.[82]

To prepare a meshed split-thickness skin graft for storage, the graft is laid on a sterile gauze swab or gauze dressing, with the epidermis of the graft next to the gauze. The gauze–graft