Surgical Dressings and Novel Skin Substitutes

Eileen Axibal, MD, Mariah Brown, MD*

KEYWORDS

• Surgical wounds • Second intention • Wound care • Dressings • Skin substitutes • Skin cancer • Dermatology • Mohs surgery

KEY POINTS

- An understanding of dressing goals and materials is necessary to optimize wound outcomes in dermatologic surgery.
- Conventional surgical dressings are best applied in a layered fashion.
- Second intention and poorly healing wounds may require the use of occlusive dressings or tissue-engineered skin substitutes.
- There are numerous skin substitute options and their utilization in dermatologic surgery is rising.

INTRODUCTION

Wounds from dermatologic surgery require meticulous care during the postoperative period. The management of acute wounds created by primary surgical incision sites and chronic wounds created by surgical sites that are healing by second intention or with slow progression are addressed in this review. Chronic wounds, such as the decubitus, neuropathic, vascular, inflammatory, and rheumatologic subtypes, are not covered, but many of the same wound care principles and techniques apply.

The concept of a surgical dressing is simple—a covering over a wound—but its importance and intricacy cannot be overstated. An ideal dressing provides pressure and hemostasis, protects the site from infection and foreign material, immobilizes surrounding tissues, cushions against mechanical trauma, provides a moist environment for healing, and wicks away blood and exudate.[1] In addition, an ideal surgical dressing should be simple to apply and maintain, nonallergenic, aesthetically pleasing, cost permissive, and easily stored.[2] Selection of the proper dressing is challenging given the wide range of wounds encountered in dermatologic surgery and the myriad dressing options available to clinicians. Although no perfect dressing exists, a thorough understanding of wound care goals and supplies allows for tailored decision making and optimal outcomes.

CONVENTIONAL SURGICAL DRESSINGS

Conventional surgical dressings are best applied in a layered fashion. The layers, from bottom to top, include ointment, contact layer, absorbent layer, contouring layer, and securing layer. Not all dressings require all components, and some materials may be useful for more than 1 layer.[1] Regardless of the specifics, the most important principles of a wound dressing are to keep the wound clean, moist, and covered.[3]

The ointment layer (**Fig. 1**) limits bacterial growth, provides hydration, and prevents the dressing from sticking to the wound. For routine dermatologic procedures, plain white petrolatum is preferred. A 2015 systematic review and meta-analysis did not show a statistically significant difference in incidence of postsurgical wound

Disclosure Statement: The authors have no commercial or financial conflicts of interest.
Mohs Micrographic Surgery and Cutaneous Oncology, Department of Dermatology, University of Colorado Hospital and School of Medicine, University of Colorado, 1665 Aurora Court, Mail Stop F703, Aurora, CO 80045, USA
* Corresponding author.
E-mail address: Mariah.Brown@ucdenver.edu

Dermatol Clin 37 (2019) 349–366
https://doi.org/10.1016/j.det.2019.03.005

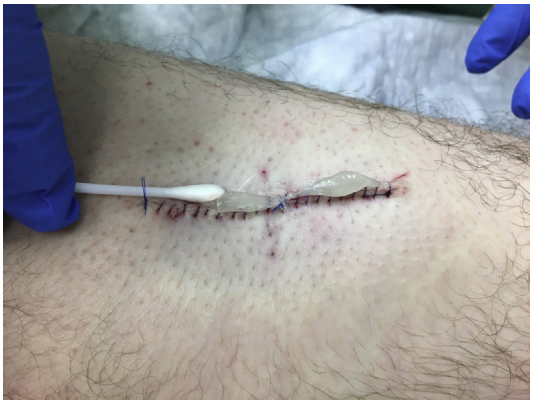

Fig. 1. Ointment layer of a conventional surgical dressing.

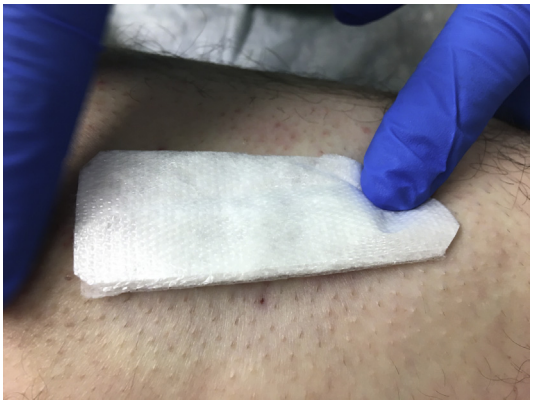

Fig. 2. Contact layer of a conventional surgical dressing.

infections between the use of topical antibiotics and petrolatum/paraffin for clean and clean-contaminated wounds.[4] There may be special circumstances in which a physician may deem the infection risk for a particular clean wound to be increased (ie, surgical site, poor personal hygiene, or contact with an individual with active infection), but there is no evidence in the literature to support the use of topical antibiotics in these cases.[5] Not only are topical antibiotics ineffective in decreasing wound infection but also they are associated with worse outcomes, such as skin edge necrosis and inflammatory chondritis.[6,7] Notably, topical antibiotics may cause allergic contact dermatitis (ACD); neomycin and bacitracin are the most common offenders, with ACD rates of 8% and 11%, respectively.[8,9] Contact allergens in commercial nonantibiotic ointments also can result in ACD. A 2013 study by Morales-Burgos and colleagues[10] showed that the rate of wound redness was higher for surgical wounds treated with Aquaphor Healing Ointment (52%) versus plain white petrolatum (12%), likely due to the allergenic ingredients lanolin and bisabolol. Lastly, topical antibiotics are contributing to emerging antibiotic resistance.[11] Despite being ineffective and posing a risk to patients, topical antibiotics continue to be used as infection prophylaxis; between 1993 and 2007, 212 million clean dermatologic procedures were performed and topical antibiotics were used in approximately 10.6 million (5.0%) of these cases.[5]

The contact layer (**Fig. 2**) touches the wound. It consists of a nonadherent material that allows exudate to pass through to the absorbent layer rather than adhere to the epithelium. The contact layer material should be chosen based on the type of wound dressed. Commonly used products include nonadherent pads (ie, Telfa, Cardinal Health, Dublin, OH, USA), impregnated gauze (eg, Xeroform [Cardinal Health, Dublin, OH, USA], Vaseline Petrolatum Gauze [Petrolatum Gauze, Cardinal Health, Dublin, OH, USA], and ADAPTIC [Non-Adhering Dressing, Acelity L.P. Inc., San Antonio, TX, USA]), paraffin gauze (eg, Jelonet [Smith & Nephew, London, UK]), silicone net dressings (eg, Mepitel [Mölnlycke Health Care, Gothenburg, Sweden]), and gas-permeable film dressings (eg, Tegaderm [3M, Maplewood, MN, USA]). Some contact dressings have antibiotics or antiseptics embedded within them (eg, Bactigras [Smith & Nephew, London, UK] and Sofra-Tulle [Hoechst Marion Roussel Ltd., Mumbai, India]).[12]

The absorbent layer (**Fig. 3**) is placed on top of the contact layer and serves to wick and retain wound exudate, so that crust and necrotic material do not accumulate on the wound.[1] A landmark study by Winter and Scales in 1963[13] demonstrated that wounds with a thick scab, as a result of being uncovered and air dried, are slower to re-epithelialize because the regenerating epidermal cells need to migrate below the eschar until they

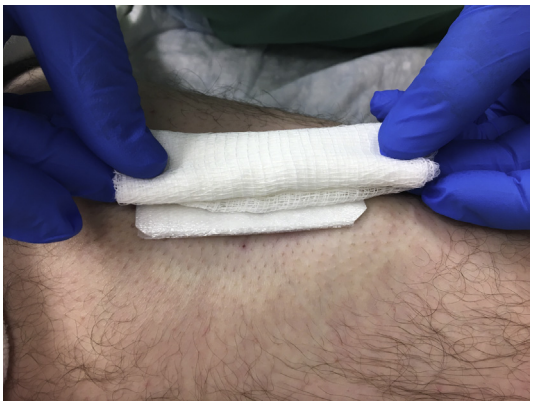

Fig. 3. Absorptive layer of a conventional surgical dressing.

reach a moist region conducive to survival.[14] Commonly used absorbent products include dry gauze pads and cotton balls. The materials can be made to be bulky or thin, depending on if pressure is required. In many cases, applying a well-padded and firmly adhesive pressure dressing and leaving it in place for 48 hours can greatly minimize bleeding complications.[15] A contour layer, if indicated, helps fill anatomic depression or support protruding structures, such as the ears and nose, so that the dressing is more secure. Dental rolls, gauze pads, and other materials may be used.

The final securing layer (**Fig. 4**) consists of tape or other wrapping materials, such as gauze rolls, tubular gauze, and elastic bandages. These materials serve to apply pressure and keep the underlying layers in place. Stretchable porous fabric and paper tape should be used in patients with fragile skin. Commonly used fabric tapes include Hypafix (BSN Medical, Hamburg, Germany), Medipore (3M, Maplewood, MN, USA), and Mefix (Mölnlycke Health Care, Gothenburg, Sweden). Hypafix uses a water-insoluble adhesive that is retained in the presence of moisture but can be removed easily with peanut or olive oil.[16] Paper tapes, such as Steri-Strips (3M, Maplewood, MN, USA) and Micropore (3M, Maplewood, MN, USA), often are placed over incision lines postoperatively and may constitute the entire dressing. They are latex-free and hypoallergenic and prevent stretching of the wound by reducing shear forces and tension on the wound edges.[17] They have the added benefit of preventing excessive soft tissue formation, thus reducing scar volume as well as keeping the wound moist and minimizing scab formation.[18] It is important to consider the potential for iatrogenic vascular insufficiency from circumferential securing bandages, particularly on the digits. With little manipulation, dressings may lift and roll distally up a digit and result in hypoxia and tissue necrosis. To prevent this tourniquet effect, digital dressings should also include the hand and wrist.[19]

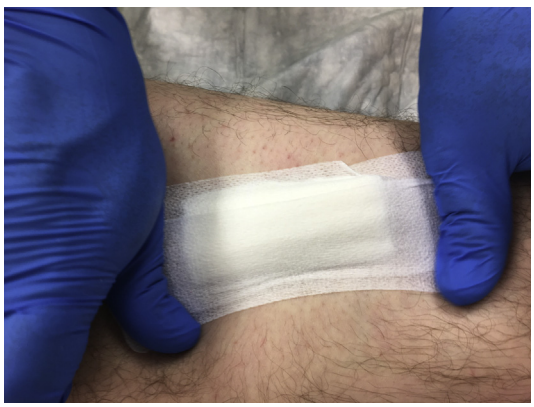

Fig. 4. Securing layer of a conventional surgical dressing.

When the dressing principles discussed previously, are followed, acute incisional wounds tend to progress in a sequenced fashion through the 4 major phases of wound healing: coagulation, inflammation, proliferation, and remodeling. When a wound becomes stalled in 1 of the stages of healing, it becomes a chronic wound.[20] In chronic wounds, elevated inflammatory cytokines, matrix metalloproteinases, and oxygen-free radicals result in destruction of extracellular matrix components and growth factors that are essential for healing.[21,22] Second intention surgical wounds that display minimal signs of healing after approximately 4 weeks also classify as chronic wounds, and they present challenges to surgeon and patient. Because the underlying tissue is exposed in second intention healing wounds, wound beds may be more susceptible to infection, pain, desiccation, and additional trauma. In the past, standard management of chronic wounds was with wet-to-dry gauze dressings; the problem lies in that these dressings become adherent to the wound bed once dry and result in reinjury, pain, and delayed wound healing on removal.[23] Gauze dressings do not support optimal healing and are more labor intensive to use than modern occlusive dressings and skin substitutes.[3,24]

OCCLUSIVE DRESSINGS

Occlusive dressings typically are divided into 5 major groups: films, foams, hydrogels, hydrocolloids, and alginates. Common trade names are listed in **Table 1**. Newer hydrofiber and hydroconductive dressings also are available. The designs of occlusive dressings are constantly changing, with the goal of improved and simplified care for a greater range of wounds. Composite dressings, which combine 2 or more types of semiocclusive dressings into 1 product, also are available. The goal of occlusive dressings is to prevent wound desiccation and maintain an optimal physiologic wound-healing environment. The decision of which type of occlusive dressing to use is guided based on the type of wound being managed. Although these materials often are used for chronic nonhealing wounds, there also is evidence for the use of occlusive dressings in acute postoperative surgical sites healing by second, and occasionally primary, intention (see **Table 1**).

Films

Film dressings are thin, flexible, transparent polyurethane or copolyester sheets with an acrylic self-adhesive backing. Oxygen, water vapor, and carbon

Table 1
List of selected occlusive dressing materials

Type	Examples
Films	Tegaderm (3M, Maplewood, MN, USA) Mepore Film (Mölnlycke, Gothenburg, Sweden) Suresite (Medline Industries, Northfield, IL, USA) Kendall Polyskin II (Cardinal Health, Dublin, OH, USA) OPSITE (Smith & Nephew, London, UK) DermaView II (DermaRite Industries, North Bergen, NJ, USA) Silon-TSR (Bio Med Sciences, Allentown, PA, USA)
Foams	Mepilex and Lyofoam (Mölnlycke) ALLEVYN (Smith & Nephew) Kendall Foam (Cardinal Health) Biatain Foam (Coloplast, Humlebaek, Denmark) HydraFoam (DermaRite Industries, North Bergen, NJ, USA) Sof-Foam and Biopatch (Johnson & Johnson, New Brunswick, NJ, USA) PolyMem (Ferris Mfg. Corp, Fort Worth, TX, USA)
Hydrogels	AquaFlo (Cardinal Health, Dublin, OH, USA) Aquasite Hydrogel Sheet (Derma Sciences, Princeton, NJ, USA) Nu-Gel (Johnson & Johnson) Clearsite (ConMed, Utica, NY, USA) 2nd Skin (Spenco, Waco, TX, USA) Vigilon (Bard, Murray Hill, NJ, USA)
Hydrocolloids	DuoDERM (Convatec, Deeside, UK) Exuderm (Medline, Northfield, IL, USA) N-Terface (Winfield Labs, Richardson, TX, USA) Comfeel (Coloplast, Humlebaek, Denmark) NU-DERM (KCI - An Acelity Company, San Antonio, TX, USA) REPLICARE (Smith & Nephew) Tegasorb (3M)
Alginates	Algisite (Smith & Nephew) AlgiCell (Integra LifeSciences, Plainsboro, NJ, USA) Kaltostat (ConvaTec) Kalginate (DeRoyal, Powell, TN, USA) Melgisorb (Mölnlycke) Sorbsan (Aspen Medical Europe Limited, Ashby-de-la-Zouch, UK)

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dioxide can permeate films, but bacteria and water cannot. Film dressings allow for a moist healing environment but do not have any absorptive capabilities, so they should not be used in wounds with excessive exudate or signs of infection.[25] In the postoperative setting, films may be used to cover primarily closed incisions, second intention surgical sites, and skin graft donor sites. They also may be used as a secondary dressing over other dressing materials. In 1991, Rubio[26] published a report of 3637 surgical incisions that were covered with a semiocclusive, transparent film dressing and found that, compared with conventional gauze dressings, the film dressing resulted in faster wound healing, decreased pain, and less scarring. No patient exhibited any symptoms of wound infection, and the dressing allowed for visual monitoring of the site. Because they are flexible, film dressings are easy to apply and they maximize patient range of motion.[27] Films can be left in place for up to 7 days but often need to be changed a few times per week.

Foams

Foam dressings are composed of an opaque polyurethane or silicone sponge-like polymer with a semiocclusive hydrophobic backing. They are permeable to both gases and water vapor and impermeable to fluid and bacteria. They are highly absorbent and provide cushion and thermal insulation. Foam dressings are indicated for moderate to heavy exudative wounds, granulating or slough-covered wounds, and graft donor sites.[25] They are too drying for wounds with little to no exudate. Two studies have demonstrated that foams are superior to gauze dressings in terms of pain reduction, nursing time, cost effectiveness, and patient satisfaction for second intention surgical wounds.[28,29] Foams can be either adhesive or nonadhesive, and a secondary dressing is required for the latter. The dressings should be

changed once saturated with exudate; this can range from once daily to once or twice weekly.

Hydrogels

Hydrogel dressings are made of cross-linked starch polymers in 80% to 90% water base and are available as free-flowing gels, flexible sheets, and impregnated gauze. They are semitransparent and semipermeable to gases and fluid. Hydrogels donate fluid to dry wounds, promoting autolytic débridement, granulation, and re-epithelialization.[23] They have limited absorptive capacity due to their high water content and, as a result, should not be used in highly exudative or bleeding wounds. Hydrogels reduce the temperature of a wound bed by up to 5°C and, because of this cooling effect, can decrease perceived pain.[25] A 1993 study comparing the use of a hydrogel sheet dressing versus a hydrocolloid dressing on 8 full-thickness circular surgical wounds produced on the backs of micropigs showed a more rapid rate of closure and re-epithelialization with the hydrogel dressing.[30] Geronemus and Robins[31] also found that, in pigskin split-thickness wounds, 100% of hydrogel-treated wounds were healed by postoperative day 4 compared with 32% of open-air wounds. Hydrogels require a secondary dressing and should be changed approximately every 1 day to 3 days depending on the hydration status of the wound. Care must be taken to ensure the dressing changes are frequent enough to avoid maceration of the surrounding skin.[20]

Hydrocolloids

Hydrocolloid sheet dressings consist of an inner, self-adhesive layer composed of a hydrophilic polymer matrix with dispersed gelatin, pectin, and other substances; this material turns into a gel with absorption. The outer layer usually consists of polyurethane and protects the wound from bacteria, foreign debris, and shear forces.[25] Hydrocolloids also are available in pastes and powders. The dressing is semipermeable to water and gas vapors but impermeable to fluid and bacteria. Hydrocolloid dressings help promote a moist healing environment, autolytic débridement, angiogenesis, and granulation tissue formation. The ideal surgical wound is one with low to moderate exudate. In 2013, Nguyen and colleagues[32] published a technique of using hydrocolloid dressings on a Mohs surgery defect on the vertex scalp with exposed bone devoid of periosteum; the dressings allowed for the development of robust granulation tissue amenable to successful delayed full-thickness skin grafting. Hydrocolloids are waterproof and cushioned and do not require a secondary dressing, so they are convenient to use.[2] Hydrocolloids should be kept in place until drainage is noted beneath the dressing; this typically requires once-daily changes early in the treatment course, with a decrease to every 3 days to 7 days over time.

Alginates

Alginates are made up of soft, nonwoven alginic acid fibers, a cellulose-like polysaccharide derived from seaweed, covered in calcium and sodium salts. They are used most widely in sheet form, but ribbons and ropes also are manufactured and can be used to pack deeper wounds. When placed on a wound, sodium ions in the exudate are exchanged for calcium ions in the dressing, resulting in the formation of a hydrophilic gel.[33] Alginates are highly absorbent (15–20× their weight in fluid), nonadherent, and biodegradable.[27] They are the optimal dressing choice for highly exudative wounds. Because the calcium ions released from the dressing activate prothrombin in the clotting cascade, they also are helpful for hemostasis.[34] The entangled fibrous structure of the dressing contributes further to coagulation. Alginates have no hydration properties and thus should be avoided in dry wounds. They require a secondary dressing and should be changed up to weekly or until the gel loses its viscosity. Because they are soluble and can be removed by saline irrigation, alginate dressings changes are less painful. The yellow-brown color and malodorous smell of alginates may be falsely mistaken for infection.

HYDROFIBER AND HYDROCONDUCTIVE DRESSINGS

Hydrofiber dressings (Aquacel) are newly developed and consist of sodium carboxymethylcellulose prepared as fibers that form a band or plate. The hydrofibers are structurally and functionally similar to alginate fibers, turning into a gel once in contact with wound exudate.[35] The dressing is comfortable, easy to remove, and indicated for heavily exudative or infected wounds; the dressing can increase its weight up to 25-fold. Hydrofibers may be left in place for up to 3 days to 7 days or until saturated.[25]

Hydroconductive dressings (Drawtex) work via capillary, hydroconductive, and electrostatic action. The dressing uses 2 types of absorbent cross-action structures that facilitate the movement of large volumes of exudate, bacteria, and debris away from the wound bed into the dressing core. It provides a 90% reduction in bacterial numbers over a 24-hour period and can hold up to 8-times to 50-times its own weight, thus proving useful for highly exudative wounds.[25,36]

COMPARATIVE OUTCOMES BETWEEN CONVENTIONAL AND OCCLUSIVE DRESSINGS

Evidence comparing outcomes between gauze-based versus occlusive surgical wound healing comes mainly from the general surgery and wound care literature. For incisional wounds, although gauze dressings are not inferior with regard to cosmetic appearance or healing time, they require more frequent dressing changes and are less comfortable.[37,38] For second intention wounds, some studies report quicker healing times with occlusive dressings.[39,40] Other studies conclude that occlusive dressings do not lead to reduction in wound healing time or pain, and the decreased frequency of dressing change does not balance its higher cost.[41]

ANTIMICROBIAL DRESSINGS (SILVER, POLYHEXAMETHYLENE BIGUANIDE, IODINE, AND HONEY)

To prevent antibiotic resistance, dressings containing nonantibiotic antimicrobial compounds may be used for infected or high-risk wounds. Silver has strong and broad-spectrum antimicrobial characteristics. Silver cations exert antimicrobial activity by disruption of the cell wall, deactivation of cellular enzymes, and prevention of transcription by attaching to DNA.[42] In the past, the use of silver was limited due to its toxicity to humans, but, more recently, nanostructured silver particles with a high surface area (and therefore a higher area-to-volume ratio) have been developed, which demonstrate greater efficacy against bacteria and less toxicity to humans.[43] A 2010 systematic review and meta-analysis showed that silver-impregnated dressings may improve short-term wounds and ulcers, but long-term data on complete wound healing are insufficient.[44] Polyhexamethylene biguanide (PHMB), a low-molecular-weight polymer with a structure related to chlorhexidine, also may be used in surgical dressings. A 2012 study by Eberlein and colleagues[45] compared the use of PHMB-containing biocellulose wound dressing against silver dressings in painful, critically colonized, and locally infected wounds and found that PHMB dressings were significantly faster and better at removing the bacterial load. It has been demonstrated, however, that soaking tie-over bolster dressings with PHMB solution in full-thickness skin grafting had no effect on postoperative bacterial loads and rather increased the risk of surgical site infection.[46] Iodine also is considered a broad-spectrum antimicrobial and is available in several dressing forms. Vermeulen and colleagues'[47] 2010 systematic review of iodine in wound care demonstrated that iodine did not lead to a reduction or prolongation of wound-healing time compared with other antiseptic wound dressings. Some of the individual trials, however, did show that iodine had significant superiority to paraffin dressings, zinc paste, silver sulfadiazine cream, and chlorhexidine dressings but was inferior to topical rifamycin dressings. Medical grade manuka honey from New Zealand and Australia is

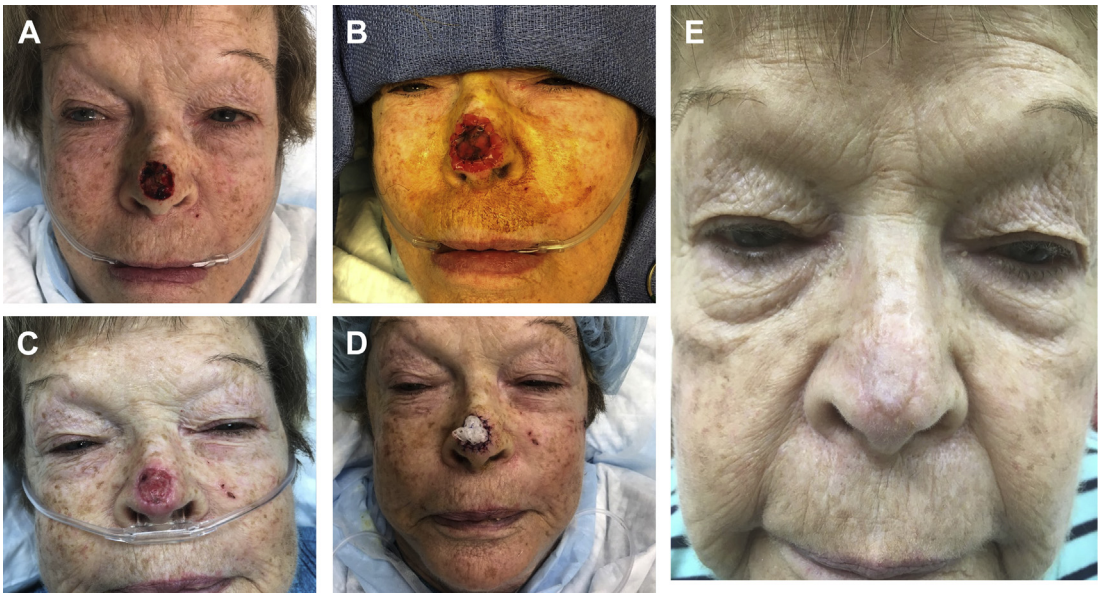

Fig. 5. Mohs surgical defect on the nasal tip (*A*). Bovine dermal regeneration template sutured into place (*B*). Three weeks later, before (*C*) and after (*D*) full-thickness skin graft placement. Three-month follow-up (*E*).

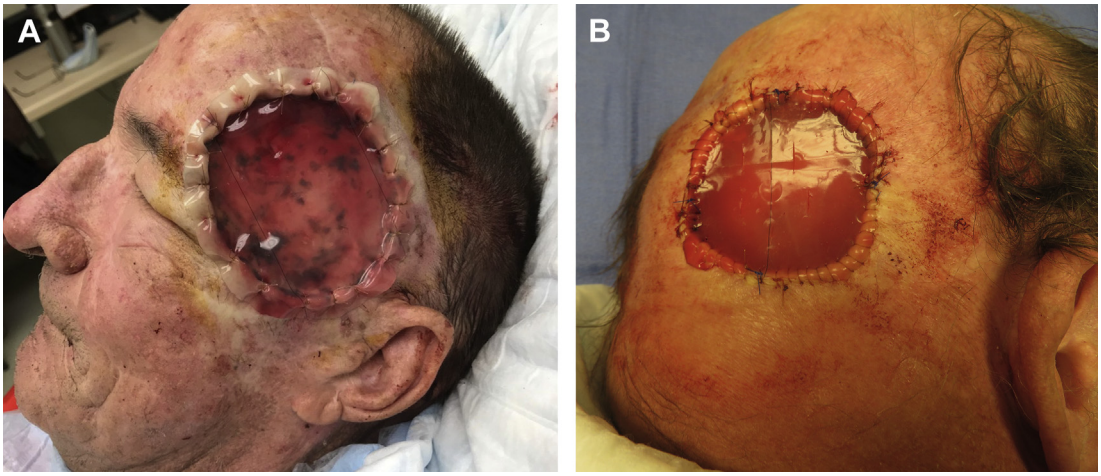

Fig. 6. Bovine dermal regeneration template sutured into large surgical defects on the left temple (*A*) and right occipital scalp (*B*).

believed to have antibacterial activity that can inhibit many bacterial species.[48] Manuka honey is available both as topical preparations (gel and paste) or impregnated into occlusive dressings (MEDIHONEY). Although there is evidence from different animal models that honey may accelerate healing compared with conventional dressings, the most recent Cochrane review in 2015 demonstrated only low-quality evidence showing that medical-grade honey heals infected postoperative wounds more quickly than antiseptics and gauze.[49,50] Nonmedical honey should not be used in wounds, because it may contain microbes and spores that can contaminate wounds.[2]

SKIN SUBSTITUTES

The advent of tissue-engineered skin substitutes has revolutionized the therapeutic potential for second intention and recalcitrant surgical wounds.[51] The goal of a skin substitute is to provide matrix materials, cells, and other key healing elements that are diminished in granulating or chronic wounds.[52,53] Unlike the other dressings, discussed previously, these materials are biodegradable and ultimately are replaced by a patient's own tissue. Skin substitutes are categorized into 3 types: epidermal, dermal, and composite (both epidermal and dermal). Dermal skin substitutes are divided further into acellular and cellular. The materials these grafts comprise may be biologic or synthetically manufactured; biologic skin substitutes are derived from a patient's own skin (autograft), another person's skin (allograft), or animals (xenograft).[54]

Epidermal Skin Substitutes

Epidermal autografts (EpiCel, EpiDex, and Laserskin) and allografts have been carried out by culturing keratinocytes from a patient's own skin and donor skin, respectively. The donor skin may be from cadavers, elective surgery patients, or neonatal foreskin (Celaderm).[55] Although they have been used to treat conditions, such as pyoderma gangrenosum, epidermolysis bullosa, severe second-degree burns, and chronic lower extremity ulcers, their use in postsurgical wounds is limited; this is because epidermal autografts take approximately 3 weeks to 4 weeks to cultivate, are extremely friable, and have a high risk of infection and poor graft take.[54,56–58]

Dermal Skin Substitutes

Dermal skin substitutes are of greater dermatologic relevance and can be divided into acellular and cellular products. Acellular dermal matrices comprise materials similar to the host extracellular matrix and function both as a barrier to fluid loss and contamination and as a template for dermal regeneration and angiogenesis.[53,59] They tend to be less expensive, be easier to produce and store, and incorporate better into the host tissue than

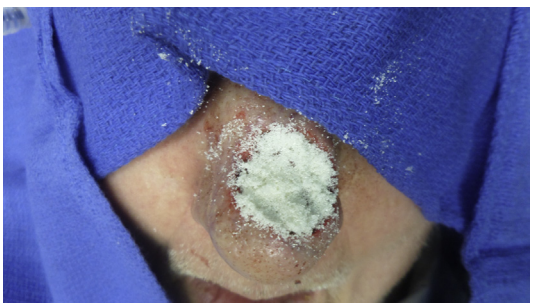

Fig. 7. Application of porcine urinary bladder matrix to a second intention Mohs surgical defect on the nasal supratip.

Fig. 8. Large basal cell carcinoma on the left temple (*A*). Surgical defect after Mohs micrographic surgery (*B*). Rotation flap with second intention and porcine xenograft sutured into place (*C*). Three-month follow-up (*D*). One-year follow-up, after small full-thickness skin graft placement (*E*).

cellular matrices due to their decreased antigenicity.[53,58,60] Cellular dermal matrices are composed of structural dermal scaffold as well as viable donor fibroblasts. These fibroblasts supply cytokines and growth factors required for wound healing.[58] The source of cells in these products are derived from human neonatal foreskin or maternofetal membranes. Both cellular and acellular grafts provide a barrier from the environment, protection against infection, and reduced wound pain.

Acellular dermal allografts (AlloDerm/Cymetra, AlloMax, DermaMatrix, GRAFTJACKET, FlexHD, and DermACELL) provide a scaffold into which host tissue integrates and revascularizes. They are believed to provide vascular linkage within 3 days of transplantation versus the 2 weeks to 3 weeks observed with xenografts.[58] These products have been used in patients with Mohs micrographic surgery defects as an alternative to granulation or as a bridge to split-thickness or full-thickness grafting.[61–64] Bovine (Integra and Matriderm) and porcine (Oasis, Cytal/MatriStem, and EZ Derm) acellular dermal xenografts have been used successfully in dermatologic surgery reconstruction. They are advantageous for deep wounds or those with bone, tendon, or cartilage exposure, allowing for pain reduction and dermal regeneration prior to definitive repair.[55,58] Examples of the application and outcomes of wounds treated with Integra, MatriStem, and EZ Derm can be seen in **Figs. 5–8**. Rogge and colleagues[65] published a series of 11 patients with calvarium-exposed scalp defects who underwent bovine xenograft placement and found that they had had increased rates of healing compared with second intention alone. Yang and Ochoa[66] demonstrated, by reviewing 225 porcine xenografts placed for Mohs and surgical excision defects, that they are safe and suitable methods to augment second intention healing and are applicable to many different sites and patient settings. Marzolf and colleagues'[67] retrospective review of

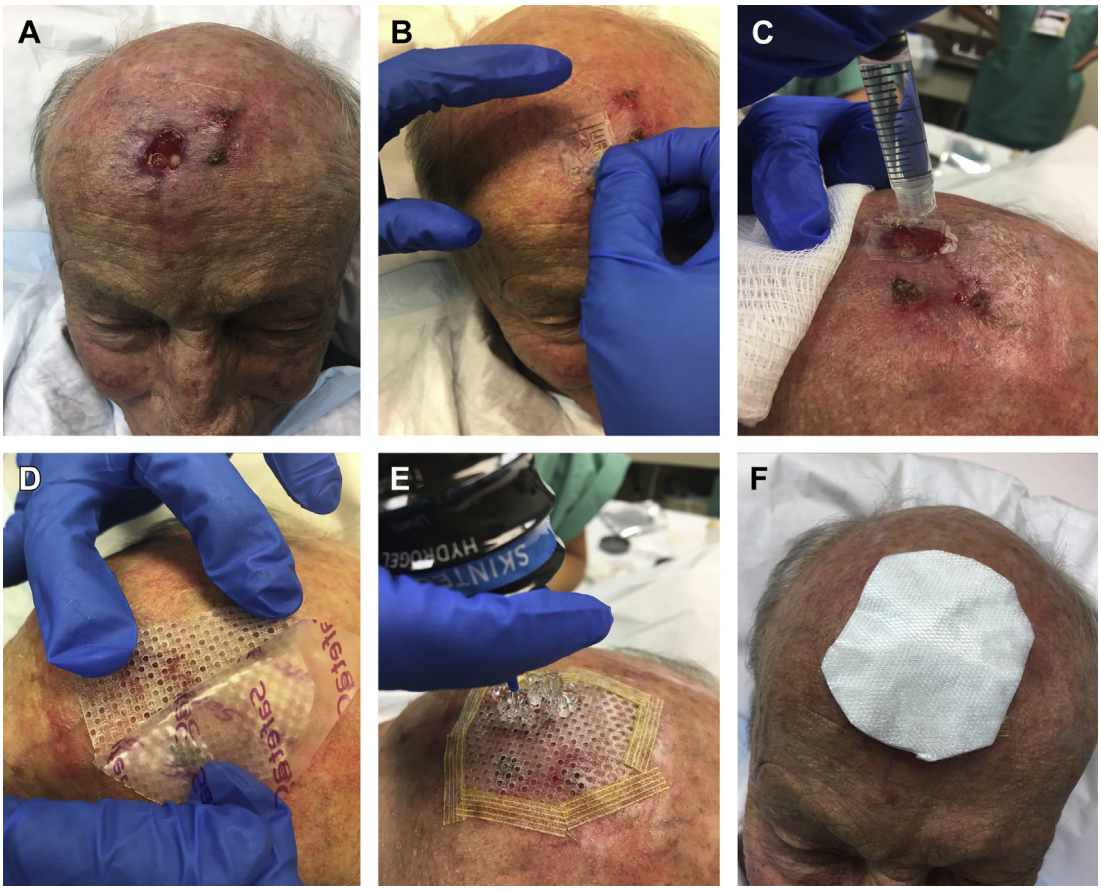

Fig. 9. Second intention wound of the midfrontal scalp (*A*). Application of dehydrated human amnion-chorion membrane (*B*). Hydration of the substitute with drops of sterile saline (*C*). Application of contact layer (*D*). Contact layer secured with paper tape and hydrated (*E*). Site covered with nonadherent pad and tape (*F*).

Table 2
Acellular dermal substitutes

Name	Manufacturer	Composition	Formulations	Storage	Application Instructions	Product Orientation
Allografts						
AlloDerm	Allergan	Dehydrated cadaveric human dermis	Sheet • AlloDerm Regenerative Tissue Matrix	Room temperature	1. Rehydrate in a 2-step bath, per instructions 2. Apply to surgical site with proper orientation	Basement membrane side: repels blood, pink when rinsed Dermal side: absorb blood, red when rinsed
			Injectable particulate form • Cymetra Micronized AlloDerm	1°C–10°C	1. Rehydrate with lidocaine 2. Draw into syringe 3. Inject onto/into wound	Meshed grafts have the letter "L" in the pattern; if you can read the letter, it is oriented properly
AlloMax Surgical Graft	C.R. Bard	Processed human dermal collagen	Sheet	Room temperature	1. Rehydrate ×5 minutes in sterile saline 2. Apply to surgical site with proper orientation 3. Suture into place	Basement membrane side: dotted, shiny, and has visible pores Dermal side: rough, with no visible pattern
DermaMatrix	Musculoskeletal Transplant Foundation/ Synthes	Donated human dermal collagen	Sheet	Room temperature	1. Rehydrate in 100 mL of saline or lactated ringers 2. Transplant onto the patient with proper orientation	Tissue notch should be on the upper left corner, facing left, when positioned correctly
GRAFTJACKET	Wright	Donated human dermis	Sheet	Room temperature	1. Rehydrate in a 5-step process, per instructions 2. Trim to dimensions 3. Apply to surgical site with proper orientation	Basement membrane side: dull, rough, buff-colored, repels blood Dermal side: Shiny, smooth, white, absorbs blood

FlexHD	Musculoskeletal Transplant Foundation	Donated human skin	Sheet	Room temperature	1. Soak in sterile solution 2. Trim to dimensions 3. Apply to surgical site with proper orientation; can be rolled or folded to desired thickness	Basement membrane side: more pigmentation, drop of blood rinsed off looks pink Dermal side: less pigmentation, drop of blood rinsed off looks red Tissue notch should be in the upper left-hand corner, facing left, when positioned correctly (epidermal side up)
DermACELL	LifeNet Health/ Stryker	Human dermis	Sheet	Room temperature	1. Immerse in sterile isotonic saline for at least 1 min, max of 4 h 2. Apply to surgical site, trim to dimensions PRN 3. Secure to wound bed/ edges with suture, staples, liquid adhesive, or Steri-Strips	Basement membrane side: duller, smaller pores, repels blood Dermal side: lighter, larger pores, absorbs blood
Xenografts						
Bovine						
Integra	LifeSciences	Dermal Regeneration Template: cross-linked bovine tendon collagen and shark-derived chondroitin-6-sulfate ± disposable semipermeable silicone layer	Sheet • Bilayer matrix (Integra Dermal Regeneration Template) • Single-layer matrix (Integra Dermal Regeneration Template Single Layer) Flowable • Integra Flowable Wound Matrix	Room temperature	1. Soak in sterile saline until ready for application 2. Cut to size 3. Place collagen layer in contact with wound bed (silicone layer facing up, if using bilayer) 4. With single layer, can place an immediate split-thickness skin graft	The outer silicone layer has a black thread and should face up

(*continued on next page*)

Table 2
(continued)

Name	Manufacturer	Composition	Formulations	Storage	Application Instructions	Product Orientation
					5. Secure with surgical tapes or suture With bilayer matrix, remove silicone layer 14–28 d later by peeling it back, can be replaced with a split-thickness skin graft	
MatriDerm (not available in United States)	MedSkin Solutions/ Dr Suwelack	Bovine collagen and elastin	Sheet • 1-mm thick • 2-mm thick	Room temperature	1. Apply onto wound bed, straight from pack 2. Rehydrate in the wound bed as needed with sterile saline 3. 1-mm thick: 1-step procedure with split-thickness skin graft placed same day 4. 2-mm thick: 2-step procedure with split-thickness skin graft placed 7 d later	N/A
Porcine						
OASIS	Smith & Nephew	Porcine small intestine submucosa	Sheet • One layer (OASIS Wound Matrix) • Three layers (OASIS ULTRA Matrix)	Room temperature	1. Cut to shape and apply onto wound bed 2. Secure with bandages (1 layer) or sutures/ staples (3 layers) 3. Hydrate with sterile saline or hydrogel 4. Cover with dressing	N/A

Cytal MatriStem	ACell	Porcine urinary bladder matrix	Sheet • Cytal Wound Matrix: 1-layer 2-layer 3-layer 6-layer	Room temperature	1. Hydrate with room temperature saline for 2–45 min (1 layer and 2 layers), 5–60 min (3 layers and 6 layers) 2. Cut sheet to desired size 3. Apply to wound bed 4. Cover with nonadherent dressing	For 2-layer, 3-layer, and 6-layer devices: the tissue notch should be in the upper right-hand corner, facing right, when positioned correctly (epidermal side up)
			Particle • MatriStem MicroMatrix	Room temperature	1. Apply powder to wound bed, lightly covering entire wound; product can be poured directly from container or hydrated with sterile saline to make a paste 2. Cover with nonadherent dressing	N/A
EZ Derm	Mölnlycke	Aldehyde cross-linked porcine dermis	Sheet Comes perforated (meshed) and nonperforated	Room temperature	1. Apply either side of product to wound in a single layer 2. Surgically fix to wound 3. Leave in place until it sloughs naturally, trimming any nonadherent dry product as needed	N/A

Table 3
Cellular dermal substitutes

Name	Manufacturer	Composition	Formulation	Storage	Application Instructions	Product Orientation
Neonatal foreskin						
Dermagraft	Organogenesis	Cryopreserved human neonatal foreskin fibroblasts seeded onto a bioabsorbable polyglactin mesh		Frozen at −75°C	1. Thaw by submerging bag a warm water bath for no more than 3 min 2. Rinse per protocol 3. Cut to size of wound bed 4. Implant into débrided wound 5. Cover with nonadherent, moist dressing 6. Start dressing changes 72 h later	N/A
Maternal/fetal membranes						
EpiFix	MeMedx Group, Inc	Dehydrated human amnion/chorion membrane: single layer of epithelial cells, a basement membrane, and an avascular connective tissue matrix that contains extracellular matrix proteins, growth factors, and cytokines	Sheet Mesh	Room temperature for up to 5 y	7. Trim EpiFix to fit 8. Place on wound bed with proper orientation 9. Hydrate with sterile saline 10. Fix to wound (if applicable) with sutures or tape 11. Cover with nonadherent contact layer 12. Apply weekly until epithelialization is achieved	Orient the product onto the wound using the letter embossment "UP" as a guide, ensuring that the it reads from left to right
Grafix	Osiris Therapeutics	Cryopreserved placental membrane	Sheet	Frozen at −80°C for up to 2 y	1. Thaw product by submerging in water or saline for no more than 15 min 2. Remove from plastic backing and apply to wound bed 3. No fixation is needed 4. Apply a nonadherent, moist dressing 5. Apply weekly	N/A

128 cases of EZ Derm application at their institution revealed that the porcine xenografts were associated with minimal pain and low rates of infection (see **Figs. 5–8**).

Cellular dermal allografts can be derived from human neonatal foreskin (Dermagraft), human amniotic/chorionic membranes (EpiFix), and placental membrane (Grafix). Fibroblasts from these allografts synthesize proteins of the extracellular matrix to stimulate wound healing but also may cause an immunologic host response. Dermagraft has been successfully used for covering intraoral defects after excision of squamous cell carcinoma, resulting in complete closure of the wounds by day 11 with no evidence of fibrosis.[68] A 2014 report described patients with nonhealing postsurgical wounds that healed with the application of EpiFix dehydrated amniotic membrane material; the material was well tolerated and the wounds did not recur with long-term follow-up.[69] **Fig. 9** demonstrates the standard application of EpiFix.

Tables 2 and **3** detail many of the currently available dermal skin substitutes. The bulk of the research and approval of these products are with regard to breast reconstruction, burns, hernia surgery, and chronic venous, diabetic, and pressure ulcers. Because wound healing principles can be extrapolated across disciplines, the relative paucity of reports within the dermatology literature should not deter specialists from utilization of these skin substitutes (see **Tables 2** and **3**).

Composite Skin Substitutes

Composite grafts have both epidermal and dermal components, thus recreating natural tissue layers. Apligraf (Organogenesis) and OrCel (Forticell Bioscience) consist of both xenogenic (bovine type I collagen) and allogeneic (live human neonatal foreskin) components. StrataGraft (Mallinckrodt Pharmaceuticals) contains human dermal fibroblasts and a fully stratified, biologically active epidermis derived from near-diploid immortalized keratinocyte S (NIKS) cells—a pathogen-free, long-lived, consistent, human keratinocyte progenitor.[70] A 2002 prospective case series by Gohari and colleagues[71] evaluated the safety and efficacy of Apligraf versus second intention healing for full-thickness Mohs and excisional surgery defects. They found that, although healing time and symptoms were similar between the groups, those treated with Apligraf had more pliable, less vascular, and more cosmetically appealing scars.

Synthetic Skin Substitutes

Biobrane (Smith & Nephew) consists of an inner layer of nylon fabric mesh that allows fibrovascular ingrowth and an outer layer of silicone that serves as a vapor and bacterial barrier.[72] The dressing is temporary and should be removed once the underlying tissue has re-epithelialized, typically in 7 days to 14 days. It has been widely used in the treatment of burns and skin graft donor sites.[73] Within dermatology, it has been used for erosive skin diseases and cosmetic procedures. A 2014 case series by Gladsjo and colleagues[74] highlighted its effective use in temporary closures, delayed reconstructions, and secondary intention healing in Mohs surgery.

Collagen Dressings

Topical wound dressings composed of type I collagen scaffolding, such as Puracol Plus (Medline), Fibracol Plus (Systagenix), or BioPad (Angelini Pharma), primarily function to absorb wound exudate and prevent desiccation of the wound rather than provide bioactive components. The benefit of these materials over standard wound dressings is that, as the scaffold absorbs liquid, it protects the wound by forming a gel and sequesters damaging matrix metalloproteinases. These products, however, typically are replaced after only a few days and thus do not function as a typical scaffold to direct tissue repair.[75] One study showed that the use of Puracol Plus, a xenograft consisting of 100% pure native bovine-derived collagen in its native triple-helix formation, can be used successfully for reconstruction of dermatologic surgical scalp wounds extending to the calvarium.[65]

SUMMARY

To optimize outcomes of acute and chronic surgical dermatology wounds, a sound understanding of wound care materials and principles is necessary. Dressings are constantly undergoing innovation and investigation, and this review highlights the current landscape of wound management within dermatologic surgery.

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