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REVIEW

Skin Grafting for Dermatologists: Past, Present, and Future

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Abstract

Purpose of This Review Skin grafting is a surgical procedure that involves replacing damaged or missing skin with healthy skin. This technique helps protect wounds, promotes healing, and enhances functionality and appearance. Skin grafting can be beneficial in treating burns, traumatic injuries, chronic ulcers, surgical wounds, and congenital defects, among others.

Recent Findings A range of cellular and tissue-based products (CTPs) can be employed, either in conjunction with autologous skin grafts or independently, to facilitate wound healing. Human skin allografts, sourced from donated human skin, often obtained from cadavers, serve as a valuable resource for wound protection. Allogeneic matrices, comprising neonatal fibroblasts or membranes, alongside chorion, amnion, and other placental products, provide a means to accelerate the wound healing process. Composite matrices, which combine human keratinocytes, fibroblasts, and xenogeneic collagen, provide a solution to replicate the complexity of natural skin. Moreover, acellular matrices derived from xenogeneic collagen or tissue offer a versatile platform for tissue regeneration.

Conclusion Skin grafting is a complex procedure that requires careful planning and postoperative care. Success depends on factors like the type of graft, wound management, and overall health of the patient. Skin grafting has evolved with advancements in surgery, anesthesia, and wound care and remains a crucial technique for restoring function and appearance.

Keywords Skin grafting · Cellular and tissue-based products · Wound healing

Introduction

Skin grafting is a surgical technique used to replace damaged or missing skin with healthy skin. This procedure is commonly used in various medical fields, including dermatology, plastic surgery, and burn care. The primary objective of skin grafting is to provide a protective covering for a wound or an area where the skin has been lost [1]. Skin grafts help prevent infection, reduce fluid loss, and stimulate the formation of new blood vessels and tissue formation. They aid in wound healing and improve the functionality and appearance of the affected area [2]. Skin grafts can be particularly beneficial in cases where the body's natural healing ability is compromised or when the wound is extensive. Skin grafts treat various conditions such as burns, traumatic injuries, chronic ulcers, surgical wounds, and congenital defects, among others [3].

Autologous skin grafting, including epidermal, split-thickness, and full-thickness grafting techniques, involves the transfer of a patient's skin from one area of their body to another. Cellular and tissue-based products (CTPs) are bioengineered products that mimic the structure and function of natural skin and are used to stimulate wound healing [4, 5]. A new term, cellular, acellular, and matrix-like products (CAMPs), has been proposed to better encompass the array of products now available [6]. Allograft skin grafting involves the use of donor skin from another individual or cadaver. Allografts are used as temporary covers to promote wound healing until the body can replace the graft with its own tissue.

Dermatologists often manage a variety of acute and chronic wounds that may require grafting for adequate healing [3, 7]. This review will provide an overview of skin

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grafting, special considerations involved in graft choice, different types of skin grafts and substitutes, and the latest advancements in this field.

Skin Grafting History

Skin grafting has a long history dating back 3500 years ago and has undergone significant development over time [8]. Ancient civilizations such as the Indians, Egyptians, and Romans used rudimentary techniques to apply skin from one body part to another. Sushruta, an ancient Indian physician, is considered the "father of surgery" and described techniques for reconstructing damaged noses and ears using skin grafts. Gaspare Tagliacozzi also developed techniques for reconstructing noses using skin grafts in the sixteenth and seventeenth centuries. In the nineteenth century, advancements in anesthesia and aseptic practices enabled more complex skin grafting procedures to be performed [9]. In the twentieth century, plastic and reconstructive surgery became established medical specialties leading to further refinement of skin grafting techniques. Innovations in tissue culture and graft preservation have improved the success and outcomes of skin grafting procedures [9]. Additionally, tissue engineering and regenerative medicine have introduced new possibilities for the development of laboratory-grown [10]. Today, skin grafting is a widely used procedure in various surgical fields, with continuous improvement in techniques and technologies providing better outcomes and enhanced patient care.

Special Considerations for Skin Grafting

Clinicians often utilize grafts as a treatment option for repairing, reconstructing, or improving various skin wounds. Skin grafts become necessary when other treatments have proven ineffective or when there is a need to replace extensively damaged or lost skin. Dermatologists may use skin grafts after Mohs micrographic surgery to repair surgical defects and promote healing. In some cases of refractory vitiligo, grafting healthy skin from unaffected areas can help restore skin color [11–13]. Skin grafts can treat chronic ulcers, such as venous leg ulcers or pressure ulcers, that have not responded to other therapies. Grafts can also be used for cosmetic or functional purposes.

The decision to use a graft depends on factors such as the patient's overall health, the specific skin condition being treated, the location and size of the affected area, and the likelihood of graft success [14]. Factors such as underlying medical conditions, allergies, medications, and lifestyle habits can impact healing. Dermatologists should carefully assess each case and determine the most appropriate treatment plan, which may involve grafts and other adjunct dermatologic procedures [15, 16]. Different types of grafts, like split-thickness grafts (STSGs) or full-thickness grafts (FTSGs), have varying degrees of success and are appropriate for different situations [7].

When selecting a donor site for a graft, it is helpful to choose the skin that matches the color, texture, and thickness of the recipient site. Adequate blood supply at the recipient site is also necessary for graft survival [3, 7]. Proper planning of the size and shape of the graft is essential to ensure good coverage and minimize tension, which can impact healing. It is important to note that chronic wounds are colonized, and assessing for infection and biofilm development and ensuring proper wound bed preparation are needed for graft survival. Preparing the recipient site should involve the removal of dead tissue and debris and thoroughly cleaning and dressing the wound [16]. Finally, proper graft fixation is necessary to prevent movement and ensure adequate contact between the graft and the recipient site. Techniques such as sutures, staples, or adhesive agents may achieve this. Additionally, bolster dressings, including negative pressure wound therapy (NPWT), may be used to increase the graft's contact with the wound bed [17].

Autologous Skin Grafts

An autologous skin graft involves the transfer of skin from a specific donor area to a target site within the same individual. This method is frequently used for skin reconstruction across various medical conditions. Autografts can be extracted either as STSGs or FTSGs, offering flexibility in graft thickness selection based on the defect.

Epidermal Grafting

Epidermal grafting (EG) is a type of autologous skin grafting where the epidermal layer is extracted from the donor area. EG is achieved by gently applying heat and consistent negative pressure to healthy skin, inducing the formation of blisters. The top layer of the blister, comprising the epidermis, is then removed and transplanted onto the wound site. Notably, the procedure maintains the untouched dermal layer at the donor site, ensuring the donor site heals without scarring and with minimal pain [18]. Consequently, this procedure permits outpatient autologous skin grafting without even local anesthesia. Studies have demonstrated promising outcomes in acute wounds, chronic ischemic and diabetic foot ulcers, pyoderma gangrenosum, and ulcers associated with autoimmune connective tissue diseases [19–23]. Additionally, this technique has been extensively investigated in

vitiligo cases, with studies indicating enhanced pigmentation and improved esthetic outcomes.

Split-Thickness Skin Grafting

STSGs involves harvesting a thin layer of skin that includes the epidermis and a portion of the underlying dermis from a designated donor site [24]. STSGs can effectively cover large areas of damaged skin with better survival characteristics due to reduced nutritional requirements compared to FTSGs [24]. In dermatology, STSGs are often utilized for wound healing and reconstructive purposes [25]. It is worth noting that in scenarios involving significant chronic wounds, burn patients, or sizable defects, it is possible to complement split-thickness skin grafting with CTPs. This combined approach aids in preparing the wound bed for graft integration, thereby increasing the likelihood of a successful graft outcome and reducing the necessary graft size [26]. While STSGs confer benefits such as expedited wound healing, they may lead to color, texture, and durability mismatch [25, 27]. STSGs also face higher risks of contracture and tend to be more painful than FTSGs for patients [24, 27].

Depending on graft size and patient preference, STSGs can be performed under local or general anesthesia. The most common donor sites for wounds below the neck are the lateral thigh or trunk due to their broad surface and discrete location [25]. There are a few different techniques to harvest the donor tissue detailed below:

Dermatome Utilization

To harvest a uniform depth graft, surgeons often use an air or electric-powered dermatome, an oscillating blade tool [24, 25]. The skin is cleaned and prepped with mineral oil to optimize gliding, and the dermatome initiates contact with the skin at 45° and then flattened and pulled across the skin to harvest the proper size and depth necessary [25].

Meshing Technique

Dermatomal harvesting is often complemented with meshing, a technique involving the introduction of perforations into the graft by a hand-cranked machine [25]. Meshing facilitates the expansion of the graft, with a greater meshing ratio resulting in increased graft stretch [25]. This process allows for a smaller donor site to cover a larger wound area; however, it may also delay healing due to the additional required epithelization time [25].

Pinch Grafting

Miniature or micro-sized grafts are harvested from the donor site and placed in the recipient wound for smaller defects. The grafts can be raised by forceps or by injecting local anesthetic underneath the tissue to create a small wheal for shave removal [24, 28].

Once the wound bed is prepared and the graft is in place, the graft can be secured with sutures/staples or steri-strips in case of pinch grafting and covered with a pressure dressing [25].

Full-Thickness Skin Graft

FTSGs involve harvesting a complete section of skin that encompasses both the epidermis and the entire dermis from a donor site [29]. This graft provides a closer match in color and texture to the surrounding skin [27]. Common donor sites include the preauricular and postauricular regions, the supraclavicular fossa, and the inner arm [29]. However, due to significant donor site morbidity, FTSGs in dermatology are typically limited to small, well-vascularized surgical wounds [27, 29]. FTSGs are commonly used to repair Mohs defects [30•]. In FTSGs, the donor tissue is harvested free hand via a scalpel, and the donor site is closed with sutures [31]. Adipose tissue, if present, is trimmed from the graft, and the graft is secured to the wound via sutures, ensuring adequate contact with the wound bed [29, 30•]. A surgical bolster and pressure dressing are typically applied to the surgical site to support inosculation [30•].

Cultured Epidermal Autografts

Bioengineered skin products, or cultured epidermal autografts (CEAs), are an advanced technique for treating wounds or skin injuries. The process involves growing a patient's skin cells in a laboratory, which are then transplanted onto the wound site. These cultured cells are placed on a scaffold to promote healing, minimize scarring, and enhance overall recovery [32]. Unlike traditional grafts, CEAs require a smaller donor sample, reducing morbidity at the donor site. However, the procedure's complexity and time requirements are significant challenges that accompany its potential benefits.

Cellular and Tissue-Based Products

CTPs are specialized medical products developed to support the healing of a variety of wounds. These products mimic the role of natural skin, providing protection, promoting tissue repair, and assisting in regenerating damaged or lost skin. CTPs can be classified in multiple ways but will be categorized herein as follows:

1. Human skin allografts
2. Allogeneic matrices
3. Composite matrices
4. Acellular matrices

Robust randomized clinical trials focusing on skin substitutes remain sparse; selected studies will be highlighted within each distinct subsection below.

Human Skin Allografts

Human skin allografts involve the transplantation of skin tissue from one person to another. These grafts are typically used as temporary wound covers to provide protection, reduce pain, and promote healing. Human skin allografts are often sourced from cadaveric donors. While they can help create a conducive environment for wound healing, they are eventually rejected by the recipient's immune system due to genetic differences. They serve as a short-term solution until the recipient's skin can regenerate.

Allogeneic Matrices

Allogeneic matrices are derived from human neonatal fibroblasts obtained from foreskin tissue, which may contain metabolically active or regenerative elements. These matrices are primarily used to provide support for soft tissues, and a subset has gained approval for treating cases of full-thickness skin and soft tissue loss. This category also encompasses products sourced from amnion, chorion, placenta, or umbilical cord.

A well-studied allogeneic matrix is comprised of a dehydrated human amnion/chorion membrane (dHACM) derived from placental tissues. Clinical trials consistently highlighted their potential for chronic wound healing, particularly in cases of diabetic foot ulcers (DFUs) and venous leg ulcers (VLUs) [33–35]. Placenta-derived dHACM matrices effectively promote complete healing, reduce healing time, and improve wound size reduction for DFUs compared to standard care [36•, 37–41], even in complex DFUs or those with exposed tendon or bone [41, 42]. Additionally, placenta-derived dHACM enhances VLU treatment, accelerating complete healing and reducing time to healing compared to standard or compression therapy alone [35, 43].

When compared to a bovine-derived allogenic matrix, placenta-derived dHACMs demonstrated superiority among DFU patients, with higher wound closure rates, cost-effectiveness, and faster healing [44, 45]. Typically, placenta-derived dHACM application involves debridement, attaching the material with adhesive strips, and wound care, with reapplication assessments typically after 3–4 weeks. They offer a favorable safety profile, with no significant difference in adverse events compared to standard care [33]. Their advantages include accessibility, ease of use, minimal complications, cost-effectiveness, and potential pain reduction [33, 34, 46]. Nonetheless, further research should continue to investigate graft sourcing, preservation techniques, and the impact of clinical application on patient outcomes [47].

While dHACMs are formed by dehydrating placental tissue, there is another form of placental allogenic matrix which is made by cryopreserving intact human placental membranes (vCPM) [48]. In vCPMs, preserve placental membrane components, including viable endogenous cells in their native state. vCPMs have consistently demonstrated improved wound healing in patients with DFUs and VLUs [49]. In a comparison study with dHACMs, vCPMs revealed greater clinical effectiveness, notably significantly higher closure rates. This enhanced performance can be attributed, in part, to vCPMs preservation of the native matrix, which conserves its intrinsic functionality, including structural integrity and the biological composition of essential signaling molecules [50].

Composite Matrices

Composite matrices combine different types of materials to mimic the layered structure of natural skin. These matrices often consist of both synthetic and biological components. For example, a composite matrix might have a synthetic top layer as a protective barrier and a lower allogeneic or acellular matrix layer to support tissue regeneration. The design aims to provide immediate wound coverage and a conducive environment for tissue regrowth.

Studies with composite matrices have shown promising results in treating venous leg ulcers and diabetic foot ulcers [51]. These CTPs have demonstrated their efficacy in promoting wound closure, enhancing quality of life by reducing pain symptoms, and significantly lowering the incidence of osteomyelitis and amputations. Additionally, studies have demonstrated that when combined with autograft, composite matrices accelerate wound closure and improve tissue cosmetic appearance in burn patients compared to autograft alone [52]. However, these types of grafts are associated with high costs and have mainly been studied in recalcitrant wounds, which may limit their generalizability [53].

Acellular Matrices

Acellular matrices are tissue substitutes processed to remove cellular components while retaining the extracellular matrix. These matrices can come from various sources, including human or animal tissues. Removing cells eliminates the risk of immune rejection and allows the recipient's cells to repopulate the matrix. Acellular matrices serve as scaffolds for cell migration, tissue remodeling, and angiogenesis, ultimately aiding wound healing and tissue regeneration.

Table 1 Dressing types are listed based on the level of absorbency, indications, and commercially available products

Dressing	Indications	Examples
Transparent film dressings [71]	• Thin, flexible, and transparent dressings that adhere to the skin • Allow for inspection of the graft site without the need for frequent dressing changes • Minimal absorbent capacity	Tegaderm; Bioclusive; Mefilm; Carrafilm; Transeal
Non-adherent dressings [72]	• Minimize trauma to the graft site during dressing changes • They do not stick to the graft, therefore reducing the risk of disrupting the graft during removal	Non-stick gauze; silicone dressings; and petroleum-based dressings
Hydrocolloid dressings [72, 73]	• Form a gel-like barrier when they encounter wound exudate • Provide moist environment that protects granulation tissue	Granuflex; Tegasorb; Comfeel
Foam dressings [74]	• Absorbent and can handle a range of exudate levels • Available in various thicknesses and shapes • Provide cushion and protection to the graft site	Mepilex; Aquacel foam; Allevyn foam; Xtrasorb foam
Alginate dressings [75, 76]	• Highly absorbent, up to 20 times its weight • Use in cases of moderate to heavy exudate	Algosteril; Comfeel Alginate Dressing; Kaltostat
Gelling fiber dressings [77]	• Highly absorbent, up to 30 times its weight • Used in cases of heavy exudate	Aquacel EXTRA; Aquacel Ag Hydrofiber; Simpurity Fibergel Ag
Superabsorbent dressings [78]	• Highly absorbent • Used in cases of heavy and large levels of exudate	Drawtex; Eclypse Super Absorbent; Zetuvit Plus Silicone Border; CovaWound Superabsorbent

Acellular products are most commonly constituted from porcine and bovine tissue and are used across a wide spectrum of wounds. Randomized trials have demonstrated their effectiveness in improving wound healing, with reported success in pressure ulcers, DFUs, VLUs, mixed ulcers, and in burn injuries [54–61].

Novel Techniques

Bioprinting

Bioprinting, a newly developed tissue engineering strategy, creates three-dimensional CTPs that can be personalized to suit the patient's needs and wound characteristics [62]. It involves depositing biomaterials, living cells, and growth factors layer by layer using computer-aided design (CAD) [63]. Bioprinting allows precise control over parameters like pore size, interconnectivity, and ECM density, promoting cell adhesion and viability [63]. It can replicate the complex microarchitecture of skin and enable the production of functional artificial skin constructs [63]. Current research is investigating the potential of impregnating bioprinted graft tissue with stem cells to increase tissue vascularization and promote long-term graft survival [62, 64, 65]. Bioprinting shows promise in replicating the stratified epidermis but has not fully expanded to replicating the dermis [66].

Wound Care

During the initial stage after the skin grafting procedure, it is crucial to maintain a delicate balance between safeguarding the graft and avoiding excessive movement. This is necessary to promote the adhesion of the graft and minimize the chances of compromising the reconstruction. Other adjunctive therapies, like NPWT, can be used in cases of large skin defects [67•, 68]. Proper wound dressings are also crucial for ensuring successful skin grafts. Dressings play a vital role in protecting the graft site, regulating moisture levels, preventing infections, and promoting overall wound healing. The choice of dressing depends on various factors, such as the type and location of the graft, the patient's health, and available resources. Additionally, certain dressings impregnated with antimicrobial properties, such as silver, iodine, and honey, can be used to reduce bacterial burden [69, 70]. However, their application in grafts with live cells requires careful consideration due to the potential risk of cytotoxicity. Dressing types are listed by increasing absorbency capability, indications, and commercially available examples (Table 1).

Conclusion

Skin grafting can be a complex procedure that requires careful planning, preparation, and postoperative care. The success of the graft depends on factors like the choice of graft type, proper wound management, the patient's overall health, and comorbidities. Skin grafts have evolved significantly over time, aided by advancements in surgical techniques, bioengineered products, and wound care, as they continue to be an essential tool for wound healing.

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Compliance with Ethical Standards

Conflict of Interest The authors have no conflicts to declare. There are no Conflict of interests by the authors.

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References

Papers of particular interest, published recently, have been highlighted as:
• Of importance

1. Johnson TM, Ratner D, Nelson BR. Soft tissue reconstruction with skin grafting. J Am Acad Dermatol. 1992;27(2 Pt 1):151–65.
2. Kirsner RS, Falanga V, Eaglstein WH. The biology of skin grafts. Skin grafts as pharmacologic agents. Arch Dermatol. 1993;129(4):481–3.
3. Valencia IC, Falabella AF, Eaglstein WH. Skin grafting. Dermatol Clin. 2000;18(3):521–32.
4. Eaglstein WH, Falanga V. Tissue engineering and the development of Apligraf a human skin equivalent. Adv Wound Care. 1998;11(4 Suppl):1–8.
5. Hefton JM, Madden MR, Finkelstein JL, Shires GT. Grafting of burn patients with allografts of cultured epidermal cells. Lancet. 1983;2(8347):428–30.
6. Wu S, Carter M, Cole W, Crombie R, Kapp DL, Kim P, et al. Best practice for wound repair and regeneration use of cellular, acellular and matrix-like products (CAMPs). J Wound Care. 2023;32(Sup4b):S1–31.
7. Kirsner RS, Eaglstein WH, Kerdel FA. Split-thickness skin grafting for lower extremity ulcerations. Dermatol Surg. 1997;23(2):85–91; quiz 2–3.
8. Hauben DJ, Baruchin A, Mahler A. On the histroy of the free skin graft. Ann Plast Surg. 1982;9(3):242–5.
9. Freshwater MF, Krizek TJ. George David Pollock and the development of skin grafting. Ann Plast Surg. 1978;1(1):96–102.
10. Trent JF, Kirsner RS. Tissue engineered skin: Apligraf, a bi-layered living skin equivalent. Int J Clin Pract. 1998;52(6):408–13.
11. Tang WY, Chan LY, Lo KK. Treatment of vitiligo with autologous epidermal transplantation using the roofs of suction blisters. Hong Kong Med J. 1998;4(2):219–24.
12. Koga M. Epidermal grafting using the tops of suction blisters in the treatment of vitiligo. Arch Dermatol. 1988;124(11):1656–8.
13. Gupta S, Jain VK, Saraswat PK. Suction blister epidermal grafting versus punch skin grafting in recalcitrant and stable vitiligo. Dermatol Surg. 1999;25(12):955–8.
14. Skouge JW. Techniques for split-thickness skin grafting. J Dermatol Surg Oncol. 1987;13(8):841–9.
15. Kirsner RS, Falanga V. Techniques of split-thickness skin grafting for lower extremity ulcerations. J Dermatol Surg Oncol. 1993;19(8):779–83.
16. Kirsner RS, Bernstein B, Bhatia A, Lantis J, Le L, Lincoln K, et al. Clinical experience and best practices using epidermal skin grafts on wounds. Wounds. 2015;27(11):282–92.
17. Isaac AL, Rose J, Armstrong DG. Mechanically powered negative pressure wound therapy as a bolster for skin grafting. Plast Reconstr Surg Glob Open. 2014;2(2): e103.
18. Herskovitz I, Hughes OB, Macquhae F, Rakosi A, Kirsner R. Epidermal skin grafting. Int Wound J. 2016;13 Suppl 3(Suppl 3):52–6.
19. Hachach-Haram N, Bystrzonowski N, Kanapathy M, Edmondson SJ, Twyman L, Richards T, et al. The use of epidermal grafting for the management of acute wounds in the outpatient setting. J Plast Reconstr Aesthet Surg. 2015;68(9):1317–8.
20. Hanafusa T, Yamaguchi Y, Katayama I. Intractable wounds caused by arteriosclerosis obliterans with end-stage renal disease treated by aggressive debridement and epidermal grafting. J Am Acad Dermatol. 2007;57(2):322–6.
21. Yamaguchi Y, Yoshida S, Sumikawa Y, Kubo T, Hosokawa K, Ozawa K, et al. Rapid healing of intractable diabetic foot ulcers with exposed bones following a novel therapy of exposing bone marrow cells and then grafting epidermal sheets. Br J Dermatol. 2004;151(5):1019–28.
22. Richmond NA, Lamel SA, Braun LR, Vivas AC, Serena T, Kirsner RS. Epidermal grafting using a novel suction blister-harvesting system for the treatment of pyoderma gangrenosum. JAMA Dermatol. 2014;150(9):999–1000.
23. Yamaguchi Y, Sumikawa Y, Yoshida S, Kubo T, Yoshikawa K, Itami S. Prevention of amputation caused by rheumatic diseases following a novel therapy of exposing bone marrow, occlusive dressing and subsequent epidermal grafting. Br J Dermatol. 2005;152(4):664–72.
24. Adams DC, Ramsey ML. Grafts in dermatologic surgery: review and update on full- and split-thickness skin grafts, free cartilage grafts, and composite grafts. Dermatol Surg. 2005;31(8 Pt 2):1055–67.
25. Braza ME, Fahrenkopf MP. Split-thickness skin grafts. StatPearls. Treasure Island (FL)2024.
26. Elseth A, Nunez Lopez O. Wound Grafts. StatPearls. Treasure Island (FL)2024.
27. Prohaska J, Cook C. Skin Grafting. StatPearls. Treasure Island (FL)2024.
28. Sonthalia S, Kachhawa D. Jodhpur Technique. StatPearls. Treasure Island (FL)2024.
29. Ramsey ML, Walker B, Patel BC. Full-thickness skin grafts. StatPearls. Treasure Island (FL)2023.
30.• Davis M, Baird D, Hill D, Layher H, Akin R. Management of full-thickness skin grafts. Proc (Bayl Univ Med Cent). 2021;34(6):683–6. **This paper examines techniques for managing full-thickness skin grafts post-Mohs surgery. It discusses suturing, securing grafts, and postoperative dressing methods. In this study, absorbable sutures, like plain gut, are preferred, and the tie-over bolster is commonly used for graft securing. Other effective methods**

include polyurethane foam, sandwich, and quilting sutures. Plain white petrolatum is recommended as the least allergenic postoperative emollient.

31. Trufant JW, Marzolf S, Leach BC, Cook J. The utility of full-thickness skin grafts (FTSGs) for auricular reconstruction. J Am Acad Dermatol. 2016;75(1):169–76.
32. Still JM Jr, Orlet HK, Law EJ. Use of cultured epidermal autografts in the treatment of large burns. Burns. 1994;20(6):539–41.
33. Zelen CM, Serena TE, Denoziere G, Fetterolf DE. A prospective randomised comparative parallel study of amniotic membrane wound graft in the management of diabetic foot ulcers. Int Wound J. 2013;10(5):502–7.
34. Serena TE, Carter MJ, Le LT, Sabo MJ, DiMarco DT. EpiFix VLUSG. A multicenter, randomized, controlled clinical trial evaluating the use of dehydrated human amnion/chorion membrane allografts and multilayer compression therapy vs. multilayer compression therapy alone in the treatment of venous leg ulcers. Wound Repair Regen. 2014;22(6):688–93.
35. Tettelbach W, Cazzell S, Reyzelman AM, Sigal F, Caporusso JM, Agnew PS. A confirmatory study on the efficacy of dehydrated human amnion/chorion membrane dHACM allograft in the management of diabetic foot ulcers: a prospective, multicentre, randomised, controlled study of 110 patients from 14 wound clinics. Int Wound J. 2019;16(1):19–29.
36.• Mohammed YA, Farouk HK, Gbreel MI, Ali AM, Salah AA, Nourelden AZ, et al. Human amniotic membrane products for patients with diabetic foot ulcers. do they help? A systematic review and meta-analysis. J Foot Ankle Res. 2022;15(1):71. **This study compares using dehydrated human amnion and chorion allograft (DHACA) alongside standard wound care (SOC) versus SOC alone for treating diabetic foot ulcers (DFU). Analysis of 11 randomized clinical trials indicates that DHACA combined with SOC leads to better outcomes, including faster and more complete wound healing compared to SOC alone. The findings suggest that incorporating DHACA with SOC is a safer and more effective treatment approach for DFU patients**.
37. DiDomenico LA, Orgill DP, Galiano RD, Serena TE, Carter MJ, Kaufman JP, et al. Use of an aseptically processed, dehydrated human amnion and chorion membrane improves likelihood and rate of healing in chronic diabetic foot ulcers: a prospective, randomised, multi-centre clinical trial in 80 patients. Int Wound J. 2018;15(6):950–7.
38. Au AS, Leung WY, Stavosky JW. Efficacy of dehydrated human amnion chorion membrane in the treatment of diabetic foot ulcers: a review. J Am Podiatr Med Assoc. 2021;111(2).
39. Tettelbach W, Cazzell S, Sigal F, Caporusso JM, Agnew PS, Hanft J, et al. A multicentre prospective randomised controlled comparative parallel study of dehydrated human umbilical cord (EpiCord) allograft for the treatment of diabetic foot ulcers. Int Wound J. 2019;16(1):122–30.
40. Bianchi C, Cazzell S, Vayser D, Reyzelman AM, Dosluoglu H, Tovmassian G, et al. A multicentre randomised controlled trial evaluating the efficacy of dehydrated human amnion/chorion membrane (EpiFix((R))) allograft for the treatment of venous leg ulcers. Int Wound J. 2018;15(1):114–22.
41. Oropallo A, Goodwin A, Morrissey M, Del Pin C, Rao A. Human amnion chorion membrane allografts in the treatment of chronic diabetic foot ulcers: a literature review. Adv Skin Wound Care. 2021;34(4):1–7.
42. Rosenblum BI. A retrospective case series of a dehydrated amniotic membrane allograft for treatment of unresolved diabetic foot ulcers. J Am Podiatr Med Assoc. 2016;106(5):328–37.
43. Serena TE, Orgill DP, Armstrong DG, Galiano RD, Glat PM, Carter MJ, et al. A multicenter, randomized, controlled, clinical trial evaluating dehydrated human amniotic membrane in the treatment of venous leg ulcers. Plast Reconstr Surg. 2022;150(5):1128–36.
44. Zelen CM, Gould L, Serena TE, Carter MJ, Keller J, Li WW. A prospective, randomised, controlled, multi-centre comparative effectiveness study of healing using dehydrated human amnion/chorion membrane allograft, bioengineered skin substitute or standard of care for treatment of chronic lower extremity diabetic ulcers. Int Wound J. 2015;12(6):724–32.
45. Zelen CM, Serena TE, Gould L, Le L, Carter MJ, Keller J, et al. Treatment of chronic diabetic lower extremity ulcers with advanced therapies: a prospective, randomised, controlled, multi-centre comparative study examining clinical efficacy and cost. Int Wound J. 2016;13(2):272–82.
46. Mueller SM, Navarini AA, Itin P, Schwegler S, Laeuchli S, Goldust M, et al. Pain reduction by dehydrated human amnion/chorion membrane allograft in nondiabetic leg ulcers might be an early indicator of good response: a case series. Dermatol Ther. 2020;33(4): e13587.
47. Protzman NM, Mao Y, Long D, Sivalenka R, Gosiewska A, Hariri RJ, et al. Placental-derived biomaterials and their application to wound healing: a review. Bioengineering (Basel). 2023;10(7).
48. Gibbons GW. Grafix((R)), a cryopreserved placental membrane, for the treatment of chronic/stalled wounds. Adv Wound Care (New Rochelle). 2015;4(9):534–44.
49. Lavery LA, Fulmer J, Shebetka KA, Regulski M, Vayser D, Fried D, et al. The efficacy and safety of Grafix((R)) for the treatment of chronic diabetic foot ulcers: results of a multicentre, controlled, randomised, blinded, clinical trial. Int Wound J. 2014;11(5):554–60.
50. Cooke M, Tan EK, Mandrycky C, He H, O'Connell J, Tseng SC. Comparison of cryopreserved amniotic membrane and umbilical cord tissue with dehydrated amniotic membrane/chorion tissue. J Wound Care. 2014;23(10):465–74, 76.
51. Dai C, Shih S, Khachemoune A. Skin substitutes for acute and chronic wound healing: an updated review. J Dermatolog Treat. 2020;31(6):639–48.
52. Waymack P, Duff RG, Sabolinski M. The effect of a tissue engineered bilayered living skin analog, over meshed split-thickness autografts on the healing of excised burn wounds. The Apligraf Burn Study Group Burns. 2000;26(7):609–19.
53. Han G, Ceilley R. Chronic wound healing: a review of current management and treatments. Adv Ther. 2017;34(3):599–610.
54. Brown-Etris M, Milne CT, Hodde JP. An extracellular matrix graft (Oasis((R)) wound matrix) for treating full-thickness pressure ulcers: a randomized clinical trial. J Tissue Viability. 2019;28(1):21–6.
55. Landsman A, Roukis TS, DeFronzo DJ, Agnew P, Petranto RD, Surprenant M. Living cells or collagen matrix: which is more beneficial in the treatment of diabetic foot ulcers? Wounds. 2008;20(5):111–6.
56. Mostow EN, Haraway GD, Dalsing M, Hodde JP, King D, Group OVUS. Effectiveness of an extracellular matrix graft (OASIS Wound Matrix) in the treatment of chronic leg ulcers: a randomized clinical trial. J Vasc Surg. 2005;41(5):837–43.
57. Romanelli M, Dini V, Bertone M, Barbanera S, Brilli C. OASIS wound matrix versus Hyaloskin in the treatment of difficult-to-heal wounds of mixed arterial/venous aetiology. Int Wound J. 2007;4(1):3–7.
58. Heimbach D, Luterman A, Burke J, Cram A, Herndon D, Hunt J, et al. Artificial dermis for major burns. A multi-center randomized clinical trial. Ann Surg. 1988;208(3):313–20.
59. Heimbach DM, Warden GD, Luterman A, Jordan MH, Ozobia N, Ryan CM, et al. Multicenter postapproval clinical trial of

Integra dermal regeneration template for burn treatment. J Burn Care Rehabil. 2003;24(1):42–8.
60. Nguyen DQ, Potokar TS, Price P. An objective long-term evaluation of Integra (a dermal skin substitute) and split thickness skin grafts, in acute burns and reconstructive surgery. Burns. 2010;36(1):23–8.
61. Driver VR, Lavery LA, Reyzelman AM, Dutra TG, Dove CR, Kotsis SV, et al. A clinical trial of Integra Template for diabetic foot ulcer treatment. Wound Repair Regen. 2015;23(6):891–900.
62. Bay C, Chizmar Z, Reece EM, Yu JZ, Winocour J, Vorstenbosch J, et al. Comparison of skin substitutes for acute and chronic wound management. Semin Plast Surg. 2021;35(3):171–80.
63. Manita PG, Garcia-Orue I, Santos-Vizcaino E, Hernandez RM, Igartua M. 3D bioprinting of functional skin substitutes: from current achievements to future goals. Pharmaceuticals (Basel). 2021;14(4).
64. Abaci HE, Guo Z, Coffman A, Gillette B, Lee WH, Sia SK, et al. Human skin constructs with spatially controlled vasculature using primary and iPSC-derived endothelial cells. Adv Healthc Mater. 2016;5(14):1800–7.
65. Phua QH, Han HA, Soh BS. Translational stem cell therapy: vascularized skin grafts in skin repair and regeneration. J Transl Med. 2021;19(1):83.
66. Tarassoli SP, Jessop ZM, Al-Sabah A, Gao N, Whitaker S, Doak S, et al. Skin tissue engineering using 3D bioprinting: an evolving research field. J Plast Reconstr Aesthet Surg. 2018;71(5):615–23.
67.• Jiang ZY, Yu XT, Liao XC, Liu MZ, Fu ZH, Min DH, et al. Negative-pressure wound therapy in skin grafts: a systematic review and meta-analysis of randomized controlled trials. Burns. 2021;47(4):747–55. **This paper presents a systematic review and meta-analysis comparing the effectiveness and safety of negative-pressure wound therapy (NPWT) versus non-NPWT for patients undergoing skin grafts. Ten randomized controlled trials involving 488 patients were analyzed. Results indicate that NPWT improves the percentage of graft take, reduces days from grafting to discharge, and lowers the relative risk of re-operation without increasing adverse events. Subgroup analysis suggests that NPWT at a negative pressure of 80 mmHg is particularly beneficial. However, data on adverse events and optimal negative pressure levels are limited, highlighting the need for further research in this area**.
68. Webster J, Scuffham P, Stankiewicz M, Chaboyer WP. Negative pressure wound therapy for skin grafts and surgical wounds healing by primary intention. Cochrane Database Syst Rev. 2014(10):CD009261.
69. Subrahmanyam M. Honey dressing accelerates split-thickness skin graft donor site healing. Indian J Surg. 2015;77(Suppl 2):261–3.
70. Brown JE, Holloway SL. An evidence-based review of split-thickness skin graft donor site dressings. Int Wound J. 2018;15(6):1000–9.
71. Weller CD, Team V, Sussman G. First-line interactive wound dressing update: a comprehensive review of the evidence. Front Pharmacol. 2020;11:155.
72. Dhivya S, Padma VV, Santhini E. Wound dressings - a review. Biomedicine (Taipei). 2015;5(4):22.
73. Thomas S. Hydrocolloid dressings in the management of acute wounds: a review of the literature. Int Wound J. 2008;5(5):602–13.
74. Tiscar-Gonzalez V, Menor-Rodriguez MJ, Rabadan-Sainz C, Fraile-Bravo M, Styche T, Valenzuela-Ocana FJ, et al. Clinical and economic impact of wound care using a polyurethane foam multilayer dressing. Adv Skin Wound Care. 2021;34(1):23–30.
75. Thomas S. Alginate dressings in surgery and wound management–Part 1. J Wound Care. 2000;9(2):56–60.
76. Lee KY, Mooney DJ. Alginate: properties and biomedical applications. Prog Polym Sci. 2012;37(1):106–26.
77. Hurlow J. AQUACEL(R) Ag dressing with Hydrofiber(R) technology. Adv Wound Care (New Rochelle). 2012;1(2):104–7.
78. Atkin L, Barrett S, Chadwick P, Callaghan R, Rippon MG, Rogers AA, et al. Evaluation of a superabsorbent wound dressing, patient and clinician perspective: a case series. J Wound Care. 2020;29(3):174–82.