
Medical Policy



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***Current Policy Effective Date: 11/1/25**
(See policy history boxes for previous effective dates)

Title: Skin and Tissue Substitutes

Description

Bioengineered skin and soft tissue substitutes may be derived from human tissue (autologous or allogeneic), nonhuman tissue (xenograph), synthetic materials, or a composite of these materials. Bioengineered skin and soft tissue substitutes are being evaluated for a variety of conditions, including breast reconstruction and healing lower-extremity ulcers and severe burns. Acellular dermal matrix (ADM) products are also being evaluated for soft tissue repair.

Medical Policy Statement

Skin and tissue substitutes approved by the Centers for Medicare & Medicaid Services have been established for individuals meeting specified selection criteria. They may be useful therapeutic options when indicated.

Human tissue products are subject to the rules and regulations of banked human tissue by the American Association of Tissue Banks (AATB) and have been established for individuals meeting specified selection criteria. They may be useful therapeutic options when indicated.

Note:

- *Non-human tissues qualify for FDA approval.*
 - *Human tissues are governed by the American Tissue Bank and do not qualify for FDA approval.*
 - *United States Food and Drug Administration (FDA) approval is a prerequisite for Medicare coverage but is not the sole determining factor for medical necessity. Having a CPT code or payment amount in the Medicare fee schedule is also not sufficient.*
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Inclusionary and Exclusionary Guidelines

Inclusions:

The following skin and tissue substitutes are considered established when used according to the FDA approval^a.

- Apligraf®
- Apis®
- Atlas Wound Matrix
- Biobrane®
- Bio-conneKt® Wound Care Matrix
- BTM Wound Dressing (aka NovoSorb® BTM)
- Cytal® Burn Matrix
- Cytal® MicroMatrix™
- Cytal™ Wound Matrix (formerly MatriStem)
- Cytal® Wound Sheet
- Derma-Gide (aka Geistlich Derma-Gide™)
- Dermagraft®
- Endoform Dermal Template™
- Epicel® has FDA Humanitarian Device Approval
- E-Z Derm™
- Flexible Collagen Nerve Cuff
- Helicoll™
- Hyalomatrix®
- InnovaMatrix™ (also known as InnovaMatrix AC)
- InnovaMatrix™ FS Integra® Bilayer Matrix
- Integra® Dermal Regeneration Template
- Integra® Flowable Wound Matrix
- Intregra® Matrix Wound Dressing (formerly known as Avagen)
- Keratec Wound Dressings (Kermatrix®)
 - Keratec Keragel
 - Keraderm
 - Kerafoam
- Kerecis Limited MariGen Wound Extra
- Kerecis™ Omega3 Wound (formerly known as MeriGen)
- MediSkin®
- Microlyte® Ag
- MicroMatrix®
- Mirragen™
- NeoMatriX® Wound Matrix
- Oasis® Burn Matrix
- Oasis® Ultra Tri-Layer Wound Matrix
- Oasis® Wound Matrix
- Ologen™ Collagen Matrix
- Omeza® Collagen Matrix
- OrCel®
- Ovine Tissue Matrix (OTM)
- OviTex® PRS Long Term Resorbable
- PELNAC™ Bilayer Wound Matrix (aka: TheraGenesis®)

- Permacol™ (Covidien)
- PermeaDerm® B
- PermeaDerm® C
- PermeaDerm® Glove
- Phoenix™ Wound Matrix
- PriMatrix™ Dermal Repair Scaffold
- ProgenaMatrix™
- Puracol® and Puracol® Plus Collagen Wound Dressings
- PuraPly Antimicrobial Wound Matrix (PuraPly AM; formerly known as FortaDerm AM)
- PuraPly Micronized Wound Matrix (PuraPly MZ; formerly known as FortaDerm)
- Restrata®
- Restrata® MiniMatrix
- Strattice™
- SupraSDRM® Biodegradable Matrix Wound Dressing
- Suprathel®
- SurgiMend®
- Symphony™
- Talymed™
- TenoGlide™
- TransCyte®
- XCelliStem® Wound Powder

^a Cross reference FDA approved products in the inclusion with the information in the Regulatory section (above) for details related to coverage.

Breast reconstructive surgery using allogeneic acellular dermal matrix products^b (including each of the following: AlloDerm®, AlloMend®, Cortiva®, [AlloMax™], DermACELL™, DermaMatrix™, FlexHD®, FlexHD® Pliable™, Graftjacket®) are considered established when ONE of the following are met:

- There is insufficient tissue expander or implant coverage by the pectoralis major muscle and additional coverage is required
- There is viable but compromised or thin postmastectomy skin flaps that are at risk of dehiscence or necrosis
- The inframammary fold and lateral mammary folds have been undermined during mastectomy and reestablishment of these landmarks is needed.

Note: Various acellular dermal matrix products used in breast reconstruction have similar efficacy. The products listed are those that have been identified for use in breast reconstruction. Additional acellular dermal matrix products may become available for this indication.

Treatment of chronic, noninfected, full-thickness diabetic lower extremity ulcers is established when using the following tissue engineered skin substitutes:

- AlloPatch®^b
- Apligraf®^c
- Dermagraft®^c
- GraftJacket® Regenerative Tissue Matrix-Ulcer Repair
- Integra®, Omnigraft™ Dermal Regeneration Matrix (also known as Omnigraft™) and Integra Flowable Wound Matrix
- mVASC®

- ProgenaMatrix™^d
- Restrata® MiniMatrix
- Theraskin®

Treatment of chronic, noninfected, partial- or full-thickness lower-extremity skin ulcers due to venous insufficiency, which have not adequately responded following a 1-month period of conventional user therapy is established when using the following tissue-engineered skin substitutes:

- Apligraf®^c
- Oasis™ Wound Matrix^d
- ProgenaMatrix™^d
- Theraskin®

OrCel™ is considered established when ALL of the following criteria are met:

- Used for the treatment of dystrophic epidermolysis bullosa
- Used for the treatment of mitten-hand deformity
- Standard wound therapy has failed
- Provided in accordance with the humanitarian device exemption [HDE] specifications of the U.S. Food and Drug Administration

The following skin and tissue product(s)/substitute(s) are considered established for use in the treatment of second- and third-degree burns:

- Alloderm
- Epicel® (for the treatment of deep dermal or full-thickness burns comprising a total body surface area ≥30% when provided in accordance with the HDE specifications of the FDA)^e
- Integra® Dermal Regeneration Template^c.

^b Banked human tissue.

^c FDA premarket approval.

^d FDA 510(k) clearance.

^e FDA-approved under an HDE.

Exclusions:

All other uses of bioengineered skin and soft tissue substitutes listed above unless they are covered by Centers for Medicare & Medicaid Services

All other skin and soft tissue substitutes, including, but not limited to:

- ACell® UBM Hydrated/Lyophilized Wound Dressing
- AlloSkin™
- AlloSkin™ RT
- Aongen™ Collagen Matrix
- Architect® ECM, PX, FX
- ArthroFlex™ (Flex Graft)
- AxoGuard® Nerve Protector (AxoGen)
- BellaCell HD or SureDerm®
- CollaCare®
- CollaCare® Dental
- Collagen Wound Dressing (Oasis Research)
- CollaGUARD®

- CollaMend™
- CollaWound™
- Coll-e-Derm
- Collexa®
- Collieva®
- Conexa™
- Coreleader Colla-Pad
- CorMatrix®
- Corplex P/Theracor P/Allacor P
- Cymetra™ (Micronized AlloDerm™)
- DeNovoSkin™
- Dermadapt™ Wound Dressing
- DermaPure™
- DermaSpan™
- Derm-maxx
- DressSkin
- Durepair Regeneration Matrix®
- Endoform® Reconstructive Template (aka: OviTex Reinforced Tissue Matrix with Resorbable Polymer)
- Endoform® Reconstructive Template – Non-Absorbable (aka: OviTex IHR Reinforced Tissue Matrix; OviTex LPR Reinforced Tissue Matrix; OviTex Reinforced Tissue Matrix with Permanent Polymer [OviTex])
- *ENDURAGen*™
- Excellagen
- ExpressGraft™
- FlexiGraft®
- FlowerDerm®
- Foundation Dermal Regeneration Scaffold (DRS) Solo
- GammaGraft
- hMatrix®
- InnovaMatrix XL
- InteguPly®
- Kerecis omega3 marigen
- Keroxx™
- Matrix HD™
- MemoDerm™
- Microderm® biologic wound matrix
- Miro3D Flex Wound Matrix
- Miro3D Fibers Wound Matrix
- Miroderm®
- MiroDry
- Mochida Nerve Cuff
- MyOwn Skin™
- Myriad Matrix
- Myriad Morcells
- Myriad Morcells Fine
- Myriad Particles™
- NeoForm™

- NervAlign Nerve Cuff
- Nerve Tape
- NeuroShield
- OviTex IHR Reinforced Tissue Matrix
- OviTex LPR Reinforced Tissue Matrix
- OviTex Reinforced Tissue Matrix with Permanent Polymer (OviTex); aka: Endoform® Reconstructive Template - Non Absorbable
- OviTex Reinforced Tissue Matrix with Resorbable Polymer (aka: Endoform® Reconstructive Template
- Progenamatrix™
- PuraPly XT
- Puros® Dermis
- RegenePro™
- Reinforced Bioscaffolds
- Repliform®
- Repriza™
- Resolve Matrix™
- SimpliDerm®
- SkinTE™
- StrataGraft®
- TenSIX™ Acellular Dermal Matrix
- TheraForm™ Standard/Sheet
- TissueMend
- TruSkin™
- Tutomesh™ Fenestrated Bovine Pericardium
- Veritas® Collagen Matrix
- VersaWrap Nerve Protector
- XCM Biologic® Tissue Matrix
- XenMatrix™ AB.

Systems, kits, or devices used to prepare or construct skin or tissue substitutes including:

- Ac5 advanced wound system
- Recell® Autologous Cell Harvesting Device

CPT/HCPCS Level II Codes *(Note: The inclusion of a code in this list is not a guarantee of coverage. Please refer to the medical policy statement to determine the status of a given procedure.)*

Established codes:

15011	15012	15013	15014	15015	15016
15017	15018	15271	15272	15273	15274
15275	15276	15277	15278	15777	A2001
A2002	A2004	A2005	A2006	A2007	A2008
A2009	A2010	A2011	A2012	A2013	A2014
A2015	A2016	A2017	A2018	A2021	A2026
A4100	A6010	A6011	A6021	A6022	A6023
Q4100	Q4101	Q4102	Q4103	Q4104	Q4105
Q4106	Q4107	Q4108	Q4110	Q4113	Q4114

Q4116	Q4117	Q4118	Q4121	Q4122	Q4124
Q4127	Q4128	Q4130	Q4135	Q4136	Q4147
Q4149	Q4158	Q4161	Q4164	Q4165	Q4166
Q4182	Q4195	Q4196	Q4203	Q4222	

Other codes (investigational, not medically necessary, etc.):

A2019	A2020	A2024	A2025	A2030	A2031
A2032	A2033	A2034	A2035	C1832	C8002
Q4111	Q4112	Q4115	Q4123	Q4125	Q4126
Q4134	Q4141	Q4142	Q4143	Q4146	Q4152
Q4167	Q4175	Q4176	Q4177	Q4178	Q4179
Q4180	Q4193	Q4197	Q4200	Q4202	Q4220
Q4226	Q4238				

Note: The code(s) above may not be covered by all contracts or certificates. Please consult customer or provider inquiry resources at BCBSM or BCN to verify coverage. The term "investigational" is not meant to imply the procedure or device has not received approval by the Food and Drug Administration (FDA). Rather, the use of this term simply means the procedure or device does not meet the health plan's objective: evidence-based technology assessment based on authoritative evidence, which then leads to improved net health outcomes.

Background

SKIN AND SOFT TISSUE SUBSTITUTES

Bioengineered skin and soft tissue substitutes may be either acellular or cellular. Acellular products (e.g., dermis with cellular material removed) contain a matrix or scaffold composed of materials such as collagen, hyaluronic acid, and fibronectin. Acellular dermal matrix (ADM) products can differ in a number of ways, including by species source (human, bovine, porcine), tissue source (e.g., dermis, pericardium, intestinal mucosa), additives (e.g., antibiotics, surfactants), hydration (wet, freeze-dried), and required preparation (multiple rinses, rehydration).

Cellular products contain living cells such as fibroblasts and keratinocytes within a matrix. The cells contained within the matrix may be autologous, allogeneic, or derived from other species (e.g., bovine, porcine). Skin substitutes may also be composed of dermal cells, epidermal cells, or a combination of dermal and epidermal cells, and may provide growth factors to stimulate healing. Bioengineered skin substitutes can be used as either temporary or permanent wound coverings.

Applications

There are a large number of potential applications for artificial skin and soft tissue products. One large category is nonhealing wounds, which potentially encompasses diabetic neuropathic ulcers, vascular insufficiency ulcers, and pressure ulcers. A substantial minority of such wounds do not heal adequately with standard wound care, leading to prolonged morbidity and increased risk of mortality. For example, nonhealing lower-extremity wounds represent an ongoing risk for infection, sepsis, limb amputation, and death. Bioengineered skin and soft tissue substitutes have the potential to improve rates of healing and reduce secondary complications.

Other situations in which bioengineered skin products might substitute for living skin grafts include certain postsurgical states (e.g., breast reconstruction) in which skin coverage is

inadequate for the procedure performed, or for surgical wounds in patients with compromised ability to heal. Second- and third-degree burns are another indication in which artificial skin products may substitute for auto- or allografts. Certain primary dermatologic conditions that involve large areas of skin breakdown (e.g., bullous diseases) may also be conditions in which artificial skin products can be considered as substitutes for skin grafts. ADM products are also being evaluated in the repair of other soft tissues including rotator cuff repair, following oral and facial surgery, hernias, and other conditions.

Tissue-engineered skin represents a new approach to wound healing. A number of skin substitute products are available commercially; others are under development or awaiting approval from the United States Food and Drug Administration (FDA).

The following products are derived from human tissue (**may not be all-inclusive**) and therefore subject to the rules and regulations for banked human tissue developed by the American Association of Tissue Banks (AATB):

- Alloderm®
- AlloMax™
- AllopatchHD™
- AlloSkin®
- Arthroflex™
- BellaCell HD or SureDerm®
- Coll-e-Derm
- Cortiva™
- Cymetra®
- DeNovoSkin
- DermACELL™
- FlexHD®
- FlowerDerm®
- GammaGraft®
- GraftJacket®
- InteguPly®
- Matrix™ HD
- MemoDerm™
- MyOwn Skin™
- NeoForm™
- Purpos® Dermis
- SimpliDerm®
- SkinTE™
- Theraskin®

Nerve wraps can be used for peripheral nerve repair. They are often made from biocompatible materials like collagen, designed to encase injured peripheral nerves. It provides a barrier between the nerve and surrounding tissue, minimizing scarring and promoting a conducive environment for nerve healing. Their application is ideal for cases where the nerve is intact but needs protection from scarring or compression.

Devices, Kits and Systems used for Autologous Cell Preparation

Devices, kits and systems have been designed for the treatment of wound beds including:

- Ac5® Advanced Wound System is a self-assembling wound care matrix which uses a peptide solution that creates a nanofiber scaffold structure. Once the peptide and sterile water are mixed in a syringe, the solution is applied to the wound bed.
 - The Recell® Autologous Cell Harvesting device enables active delivery of an individual's own living cells. A small piece of the individual's skin is submerged in a heated proprietary enzymatic formulation which targets and disrupts protein-to-protein interactions, priming the cells for mechanical isolation. Once the individual cells are isolated and the cell suspension is filtered, the regenerative epidermal suspension is ready to be sprayed onto the wound bed. The spray includes keratinocytes, fibroblasts, and melanocytes.
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Summary of Evidence

Breast Reconstruction

For individuals who are undergoing breast reconstruction who receive allogeneic ADM products, the evidence includes RCTs and systematic reviews. Relevant outcomes are symptoms, morbid events, functional outcomes, quality of life, and treatment-related morbidity. A systematic review found no difference in overall complication rates with ADM allograft compared with standard procedures for breast reconstruction. Reconstructions with ADM have been reported to have higher seroma, infection, and necrosis rates than reconstructions without ADM. However, capsular contracture and malposition of implants may be reduced. Thus, in cases where there is limited tissue coverage, the available evidence may inform patient decision making about reconstruction options. The evidence is sufficient to determine that the technology results in a meaningful improvement in the net health outcome.

Tendon Repair

For individuals who are undergoing tendon repair who receive Graftjacket, the evidence includes RCT. Relevant outcomes are symptoms, morbid events, functional outcomes, quality of life, and treatment-related morbidity. The RCT identified found improved outcomes with the Graftjacket ADM allograft for rotator cuff repair. Although these results were positive, additional studies with a larger number of patients is needed to evaluate the consistency of the effect. The evidence is insufficient to determine the effects of the technology on health outcomes.

Surgical Repair of Hernias or Parastomal Reinforcement

For individuals who are undergoing surgical repair of hernias or parastomal reinforcement who receive acellular collagen-based scaffolds, the evidence includes RCTs. Relevant outcomes are symptoms, morbid events, functional outcomes, quality of life, and treatment-related morbidity. Several comparative studies including RCTs have shown no difference in outcomes between tissue-engineered skin substitutes and either standard synthetic mesh or no reinforcement. The evidence is sufficient to determine that the technology is unlikely to improve the net health outcome.

Diabetic Lower-Extremity Ulcers

For individuals who have diabetic lower-extremity ulcers who receive AlloPatch, Apligraf, Dermagraft, Integra, mVASC, or TheraSkin, the evidence includes RCTs. Relevant outcomes are symptoms, change in disease status, morbid events, and quality of life. RCTs reporting complete wound healing outcomes with at least 12 weeks of follow-up have demonstrated the efficacy of AlloPatch (reticular ADM), Apligraf and Dermagraft (living cell therapy), Integra (biosynthetic), mVASC and TheraSkin over the standard of care (SOC). The evidence is

sufficient to determine that the technology results in a meaningful improvement in the net health outcome.

For individuals who have diabetic lower-extremity ulcers who receive ADM products other than AlloPatch, Apligraf, Dermagraft, Integra, mVASC, or TheraSkin the evidence includes RCTs. Relevant outcomes are disease-specific survival, symptoms, change in disease status, morbid events, and quality of life. Results from a multicenter RCT showed some benefit of DermACELL that was primarily for the subgroup of patients who only required a single application of the ADM. Studies are needed to further define the population who might benefit from this treatment. Additional study with a larger number of subjects is needed to evaluate the effect of Graftjacket, DermACELL, Cytal, PriMatrix, and Oasis Wound Matrix, compared with current SOC or other advanced wound therapies. An RCT of Omega3 Wound (Kerecis) has been published and 2 larger RCTs are registered and reported as completed but have not been published. The evidence is insufficient to determine the effects of the technology on health outcomes.

Lower-Extremity Ulcers due to Venous Insufficiency

For individuals who have lower-extremity ulcers due to venous insufficiency who receive Apligraf or Oasis Wound Matrix, the evidence includes RCTs. Relevant outcomes are disease-specific survival, symptoms, change in disease status, morbid events, and quality of life. RCTs have demonstrated the efficacy of Apligraf living cell therapy and xenogeneic Oasis Wound Matrix over the standard of care. The evidence is sufficient to determine that the technology results in a meaningful improvement in the net health outcome.

For individuals who have lower-extremity ulcers due to venous insufficiency who receive bioengineered skin substitutes other than Apligraf or Oasis Wound Matrix, the evidence includes RCTs. Relevant outcomes are disease-specific survival, symptoms, change in disease status, morbid events, and quality of life. In a moderately large RCT, Dermagraft was not shown to be more effective than controls for the primary or secondary end points in the entire population and was only slightly more effective than controls (an 8% to 15% increase in healing) in subgroups of patients with ulcer durations of 12 months or less or size of 10 cm or less. Additional studies with a larger number of subjects is needed to evaluate the effect of the xenogeneic PriMatrix skin substitute vs the current standard of care. The evidence is insufficient to determine the effects of the technology on health outcomes.

Dystrophic Epidermolysis Bullosa

For individuals who have dystrophic epidermolysis bullosa who receive OrCel, the evidence includes case series. Relevant outcomes are symptoms, change in disease status, morbid events, and quality of life. OrCel was approved under a humanitarian drug exemption for use in patients with dystrophic epidermolysis bullosa undergoing hand reconstruction surgery, to close and heal wounds created by the surgery, including those at donor sites. Outcomes have been reported in a small series (e.g., 5 patients). The evidence is insufficient to determine the effects of the technology on health outcomes.

Deep Dermal Burns

For individuals who have deep dermal burns who receive bioengineered skin substitutes (i.e., Epicel, Integra Dermal Regeneration Template), the evidence includes RCTs. Relevant outcomes are disease-specific survival, symptoms, change in disease status, morbid events, functional outcomes, quality of life, and treatment-related morbidity. Overall, few skin substitutes have been approved, and the evidence is limited for each product. Epicel (living cell

therapy) has received FDA approval under a humanitarian device exemption for the treatment of deep dermal or full-thickness burns comprising a total body surface area of 30% or more. Comparative studies have demonstrated improved outcomes for biosynthetic skin substitute Integra Dermal Regeneration Template for the treatment of burns. The evidence is sufficient to determine that the technology results in a meaningful improvement in the net health outcome.

Rationale

Evidence reviews assess the clinical evidence to determine whether the use of a technology improves the net health outcome. Broadly defined, health outcomes are length of life, quality of life, and ability to function-including benefits and harms. Every clinical condition has specific outcomes that are important to patients and to managing the course of that condition. Validated outcome measures are necessary to ascertain whether a condition improves or worsens; and whether the magnitude of that change is clinically significant. The net health outcome is a balance of benefits and harms. The following is a summary of the key literature to date.

BREAST RECONSTRUCTION

The literature on ADM for breast reconstruction consists primarily of retrospective, uncontrolled series and systematic reviews of these studies.

A 2013 study used data from the American College of Surgeon's National Surgical Quality Improvement Program to compare ADM-assisted tissue expander breast reconstruction (n=1717) to submuscular tissue expander breast reconstruction (n=7442) after mastectomy.(5) Complication rates did not differ significantly between the ADM-assisted (5.5%) and the submuscular tissue expander groups (5.3%; p=0.68). Rates of reconstruction-related complications, major complications, and 30-day reoperation did not differ significantly between cohorts.

Systematic Reviews

Ng et al (2024) conducted a systematic review and meta-analysis comparing postoperative complications and patient-reported outcomes between patients who received ADM and those who did not.(6) Prospective cohort studies and RCTs were included (9 studies; N=3161). There were no significant differences in postoperative outcomes between the ADM and non-ADM groups for key complications such as seroma (p=.51), hematomas (p=.20), infections (p=.21), wound dehiscence (p=.09), reoperations (p=.70), implant loss (p=.27), or skin necrosis (p=.21).

A meta-analysis by Lee and Mun (2016) included 23 studies (total N=6199 cases) on implant-based breast reconstruction that were published between February 2011 and December 2014.(7) The analysis included an RCT and three prospective comparative cohort studies; the remainder was retrospective comparative cohort studies. Use of ADM did not affect the total complication rate (see Table 1). ADM significantly increased the risk of major infection, seroma, and flap necrosis, but reduced risks of capsular contracture and implant malposition. Use of ADM allowed for significantly greater intraoperative expansion (mean difference [MD], 79.63; 95% confidence interval [CI], 41.99 to 117.26; p<0.001) and percentage of intraoperative filling (MD=13.30; 95% CI, 9.95 to 16.65; p<0.001), and reduced the frequency of injections to complete expansion (MD = -1.56; 95% CI, -2.77 to -0.35; p=0.01).

Table 1. Meta-Analysis of Breast Reconstruction Outcomes With and Without ADM

Outcome Measure	Relative Risk	95% Confidence Interval	p
Infection	1.42	1.02 to 1.99	0.04
Seroma	1.41	1.12 to 1.78	0.004
Mastectomy flap necrosis	1.44	1.11 to 1.87	0.006
Unplanned return to the operating room	1.09	0.63 to 1.90	NS
Implant loss	1.00	0.68 to 1.48	NS
Total complications	1.08	0.87 to 1.34	NS
Capsular contracture	0.26	0.15 to 0.47	<0.001
Implant malposition	0.21	0.07 to 0.59	0.003

Adapted from Lee and Mun (2016).⁵

ADM: acellular dermal matrix; NS: not significant.

AlloDerm

Randomized Controlled Trials

McCarthy et al (2012) reported on a multicenter, blinded RCT of AlloDerm in two-stage expander/implant reconstruction.(8) Seventy patients were randomized to AlloDerm ADM-assisted tissue expander/implant reconstruction or to submuscular tissue expander/implant placement. The trial was adequately powered to detect clinically significant differences in immediate postoperative pain but underpowered to detect the secondary end point of pain during tissue expansion. There were no significant differences between the groups in the primary outcomes of immediate postoperative pain (54.6 AlloDerm vs 42.8 controls on a 100-point visual analog scale) or pain during the expansion phase (17.0 AlloDerm vs 4.6 controls), or in the secondary outcome of rate of tissue expansion (91 days AlloDerm vs 108 days controls) and patient-reported physical well-being. There was no significant difference in adverse events, although the total number of adverse events was small.

Comparisons Between Products

AlloDerm vs AlloMax

Hinchcliff et al (2017) conducted an RCT that compared AlloDerm with AlloMax (n=15 each) for implant-based breast reconstruction.(9) Complications were assessed 7, 14, and 30 days postoperatively and biopsies of the ADMs were taken during implant exchange. Vessel density in the AlloMax biopsies was higher than in the AlloDerm biopsies. Complications were reported in 26.1% of AlloMax cases and 8.0% of AlloDerm cases; these complication rates did not differ statistically with the 30 patients in this trial.

AlloDerm vs DermaMatrix

Mendenhall et al (2017) conducted an RCT that compared AlloDerm with DermaMatrix in 111 patients (173 breasts).(10) There were no significant differences in overall rates of complications (AlloDerm, 15.4%; DermaMatrix, 18.3%; p=0.8) or implant loss (AlloDerm, 2.2%; DermaMatrix, 3.7%; p=0.5) between the 2 ADMs at 3 months postoperative.(10) There were no statistically significant differences in the overall complication rates (6% vs. 13%; p=.3), severity of complications, or patient satisfaction between the AlloDerm and DermaMatrix groups at 2 years after definitive reconstruction.(11).

AlloDerm Versus DermACELL

Davison et al (2024) conducted a prospective randomized trial comparing AlloDerm with DermACELL in 55 patients undergoing bilateral nipple and/or skin-sparing

mastectomies.(12) Patients served as their own controls and were blinded to the random assignment of the two products to the left or right breast. The findings revealed no significant differences in drain removal time or average drain output between the two groups. However, a notable difference was observed in seroma rates, with 30.91% of AlloDerm breasts experiencing seromas compared to 14.55% in DermACELL breasts ($p<.05$). Additionally, incorporation rates were significantly higher for DermACELL at 99.8% compared to AlloDerm's 93.4% ($p<.05$). Both AlloDerm and DermACELL demonstrated a high success rate of 94.55% for reconstruction outcomes. Nonetheless, AlloDerm was associated with a higher incidence of seromas and a trend towards lower incorporation rates.

AlloDerm Versus Cortiva

Keane et al (2024) conducted an RCT comparing Cortiva with AlloDerm in patients who underwent either direct-to-implant (DTI) or tissue expander (TE) reconstruction (N=302).(13) The primary outcome measured was reconstructive failure, defined as premature explantation of TEs or DTI reconstructions before three months postoperatively. 151 patients received AlloDerm (280 breasts) and 151 received Cortiva (277 breasts). The results showed no significant difference in reconstructive failure rates between the two ADMs, with AlloDerm at 9.3% and Cortiva at 8.3% ($p=.68$). Additionally, there were no notable differences in other complications or patient-reported outcomes between the groups. Seroma formation was more prevalent in the AlloDerm group (12%) compared to Cortiva (7.6%) and was statistically significant (odds ratio: 1.93; 95% CI: 1.01 to 3.67; $p=.047$).

Strattice

Dikmans et al (2017) reported on early safety outcomes from an open-label multicenter RCT that compared porcine ADM-assisted one-stage expansion with two-stage implant-based breast reconstruction (see Table 2).(14) One-stage breast reconstruction with porcine ADM was associated with a higher risk of surgical complications, reoperation, and with removal of implant, ADM, or both (see Table 3). The trial was stopped early due to safety concerns, but it cannot be determined from this study design whether the increase in complications was due to the use of the xenogenic ADM or to the comparison between 1-stage and 2-stage reconstruction.

Table 2. Summary of Key RCT Characteristics

Author	Countries	Sites	Dates	Participants	Interventions	
					Active	Comparator
Dikmans et al (2017)	EU	8	2013-2015	Women intending to undergo skin-sparing mastectomy and immediate IBBR	59 patients (91 breasts) undergoing 1-stage IBBR with ADM	62 women (92 breasts) undergoing 2-stage IBBR

ADM: acellular dermal matrix; IBBR: implant-based breast reconstruction; RCT: randomized controlled trial.

Table 3. Summary of Key RCT Outcomes

Study	Surgical Complications	Severe Adverse Events	Reoperation	Removal of Implant, ADM, or Both
Dikmans et al (2017)				
1-stage with ADM, n (%)	27 (46)	26 (29)	22 (37)	24 (26)
2-stage with ADM, n (%)	11 (18)	5 (5)	9 (15)	4 (5)
OR (95% CI)	3.81 (2.67 to 5.43)		3.38 (2.10 to 5.45)	8.80 (8.24 to 9.40)
p	<0.001		<0.001	<0.001

Section Summary: Breast Reconstruction

Results of a systematic review found no difference in overall complication rates between ADM allograft and standard procedures for breast reconstruction. Although reconstructions with ADM have been reported to have higher seroma, infection, and necrosis rates than reconstructions without ADM, rates of capsular contracture and malposition of implants may be reduced. Thus, in cases where there is limited tissue coverage, the available studies may be considered sufficient to permit informed decision-making about risks and benefits of using allogeneic ADM for breast reconstruction.

TENDON REPAIR

Graftjacket

Barber et al (2012) reported an industry sponsored multicenter RCT of augmentation with Graftjacket human ADM for arthroscopic repair of large (>3 cm) rotator cuff tears involving two tendons.(15) Twenty-two patients were randomized to Graftjacket augmentation and 20 patients to no augmentation. At a mean follow-up of 24 months (range, 12-38 months), the American Shoulder and Elbow Surgeons score improved from 48.5 to 98.9 in the Graftjacket group and from 46.0 to 94.8 in the control group ($p=0.035$). The Constant score improved from 41 to 91.9 in the Graftjacket group and from 45.8 to 85.3 in the control group ($p=0.008$). The University of California, Los Angeles score did not differ significantly between groups. Gadolinium-enhanced magnetic resonance imaging (MRI) scans showed intact cuffs in 85% of repairs in the Graftjacket group and 40% of repairs in the control group. However, no correlation was found between MRI findings and clinical outcomes. Rotator cuff re-tears occurred in 3 (14%) patients in the Graftjacket group and 9 (45%) patients in the control group.

Rashid et al (2020) reported disruption of the native extracellular matrix with either GraftJacket or Permacol (porcine acellular dermis) as a patch overlay for rotator cuff repair in a small, controlled study with 13 patients.(16) The disruption was greater in the Permacol group and there was an immune response in 1 of 3 patients following use of the xenograft.

Section Summary: Tendon Repair

One small RCT was identified that found improved outcomes with Graftjacket ADM allograft for rotator cuff repair. Although results of this trial were promising, additional study with a larger number of patients is needed to evaluate consistency of findings and determine the effects of this technology with greater certainty.

SURGICAL REPAIR OF HERNIAS OR PARASTOMAL REINFORCEMENT

Systemic Reviews

A 2013 systematic review evaluated the clinical effectiveness of acellular collagen-based scaffolds for the repair of incisional hernias.(17) The bioprosthetic materials could be harvested from bovine pericardium, human cadaveric dermis, porcine small intestine mucosa, porcine dermal collagen, or bovine dermal collagen. Products included in the search were Surgisis, Tutomesh, Veritas, AlloDerm, FlexHD, AlloMax, CollaMend, Permacol, Strattice, FortaGen, ACell, DermaMatrix, XenMatrix, and SurgiMend. Sixty publications with 1212 repairs were identified and included in the review, although meta-analysis could not be performed. There were four level III studies (two AlloDerm, two Permacol); the remainder were level IV or V. The largest number of publications were on AlloDerm ($n=27$) and Permacol

(n=18). No publications on incisional hernia repair were identified for AlloMax, FortaGen, DermaMatrix, or ACell. The overall incidence of a surgical site occurrence (e.g., postoperative infection, seroma/hematoma, pain, bulging, dehiscence, fistula, mechanical failure) was 82.6% for porcine small intestine mucosa, 50.7% for xenogeneic dermis, 48.3% for human dermis, and 6.3% for xenogeneic pericardium. No comparative data were identified that could establish superiority to permanent synthetic meshes.

AlloDerm as an Overlay

Espinosa-de-los-Monteros et al (2007) retrospectively reviewed 39 abdominal wall reconstructions with AlloDerm performed in 37 patients and compared them with 39 randomly selected cases.(18) They reported a significant decrease in recurrence rates when human cadaveric acellular dermis was added as an overlay to primary closure plus rectus muscle advancement and imbrication in patients with medium-sized hernias. However, no differences were observed when adding human cadaveric acellular dermis as an overlay to patients with large-size hernias treated with underlay mesh.

Comparisons Between Products

AlloDerm vs Surgisis Gold

Gupta et al (2006) compared the efficacy and complications associated with use of AlloDerm and Surgisis bioactive mesh in 74 patients who underwent ventral hernia repair.(19) The first 41 procedures were performed using Surgisis Gold 8-ply mesh formed from porcine small intestine submucosa, and the remaining 33 patients had ventral hernia repair with AlloDerm. Patients were seen 7 to 10 days after discharge from the hospital and at 6 weeks. Any signs of wound infection, diastasis, hernia recurrence, changes in bowel habits, and seroma formation were evaluated. The use of the AlloDerm mesh resulted in 8 (24%) hernia recurrences. Fifteen (45%) of the AlloDerm patients developed a diastasis or bulging at the repair site. Seroma formation was only a problem in 2 patients.

AlloDerm vs FlexHD

A 2013 study compared AlloDerm with FlexHD for complicated hernia surgery.(20) From 2005 to 2007, AlloDerm was used to repair large (>200 cm²) symptomatic complicated ventral hernias that resulted from trauma or emergency surgery (n=55). From 2008 to 2010, FlexHD was used to repair large, complicated ventral hernias in patients meeting the same criteria (n=40). The two groups were comparable at baseline. At one year follow-up, all AlloDerm patients were diagnosed with hernia recurrence (abdominal laxity, functional recurrence, true recurrence) requiring a second repair. Eleven (31%) patients in the FlexHD group required a second repair. This comparative study is limited by the use of nonconcurrent comparisons, which is prone to selection bias and does not control for temporal trends in outcomes.

FlexHD vs Strattice

Roth et al (2017) reported on a prospective study assessing clinical and quality of life outcomes following complex hernia repair with a human (FlexHD) or porcine (Strattice) ADM.(21) The study was funded by the Musculoskeletal Transplant Foundation, which prepares and supplies FlexHD. Patients were enrolled if they had a hernia at least six cm in the transverse dimension, active or prior infection of the abdominal wall, and/or enterocutaneous fistula requiring mesh removal. Eighteen (51%) of the 35 patients had undergone a previous hernia repair. After abdominal wall repair with the ADM, 20 (57%) patients had a surgical site occurrence, and nearly one-third had hospital readmission. The

type of biologic material did not impact hernia outcomes. There was no comparison with synthetic mesh in this study, limiting interpretation.

Strattice vs Synthetic Mesh

Bellows et al (2014) reported early results of an industry-sponsored multicenter RCT that compared Strattice (non-cross-linked porcine ADM, n=84) with a standard synthetic mesh (n=88) for the repair of inguinal hernias.(22) The trial was designed by the surgeons and was patient- and assessor-blinded to reduce risk of bias. Blinding continued through two years of follow-up. The primary outcome was resumption of activities of daily living at one year. Secondary outcomes included complications, recurrences, or chronic pain (i.e., pain that did not disappear by three months post-surgery). At three-month follow-up, there were no significant differences in either the occurrence or type of wound events (relative risk, 0.98; 95% CI, 0.52 to 1.86). Pain was reduced from one to three days postoperative in the group treated with Strattice, but at three month follow-up pain scores did not differ significantly between groups.

Strattice Versus No Reinforcement

Also, in 2014, the PRISM Study Group reported a multicenter, double-blinded, randomized trial of Strattice for parastomal reinforcement in patients undergoing surgery for permanent abdominal wall ostomies.(23) Patients were randomized to standard stoma construction with no reinforcement (n=58) or stoma construction with Strattice as parastomal reinforcement (n=55). At 24-month follow-up (n=75), the incidence of parastomal hernias was similar for the two groups (13.2% of controls, 12.2% of study group).

Adverse Events

Permacol (porcine acellular dermal matrix) was reported in a case series of 13 patients to result in recurrent intestinal fistulation and intestinal failure when used for abdominal reconstructive surgery.(24)

Section Summary: Surgical Repair of Hernias or Parastomal Reinforcement

Current evidence does not support a benefit of ADMs in hernia repair or prevention of parastomal hernia. Additional RCTs are needed to compare biologic mesh with synthetic mesh and to determine if there is a patient population that would benefit from these products.

DIABETIC LOWER-EXTREMITY ULCERS

Systematic Reviews

A 2016 Cochrane review evaluated skin substitutes for the treatment of diabetic foot ulcers.(25) Seventeen trials (N=1655) were included in the meta-analysis. Most trials identified were industry-sponsored, and an asymmetric funnel plot indicated publication bias. Pooled results of published trials found that skin substitutes increased the likelihood of achieving complete ulcer closure compared with standard of care (SOC) alone (relative risk, 1.55; 95% CI, 1.30 to 1.85). Use of skin substitutes also led to a statistically significant reduction in amputations (relative risk, 0.43; 95% CI, 0.23 to 0.81), although the absolute risk difference was small. Analysis by individual products found a statistically significant benefit on ulcer closure for Apligraf, EpiFix, and Hyalograft-3D. The products that did not show a statistically significant benefit for ulcer closure were Dermagraft, Graftjacket, Kaloderm, and OrCel.

Apligraf, Dermagraft, AlloPatch, Integra Dermal Regeneration Template, Integra Flowable Wound Matrix, mVASC, or TheraSkin

Apligraf

Veves et al (2001) reported on a randomized prospective trial on the effectiveness of Apligraf (previously called Graftskin), a living skin equivalent, in treating noninfected nonischemic chronic plantar diabetic foot ulcers.(26) The trial involved 24 centers in the United States; 208 patients were randomized to ulcer treatment with Apligraf (112 patients) or saline-moistened gauze (96 patients, control group). Standard state-of-the-art adjunctive therapy, including extensive surgical débridement and adequate foot off-loading, was provided in both groups. Apligraf was applied at the beginning of the study and weekly thereafter for a maximum of 4 weeks (maximum of five applications) or earlier if complete healing occurred. At the 12-week follow-up visit, 63 (56%) Apligraf-treated patients achieved complete wound healing compared with 36 (38%) in the control group ($p=0.004$). The Kaplan-Meier method median time to complete closure was 65 days for Apligraf, which was significantly lower than the 90 days observed in the control group ($p=0.003$). The rates of adverse reactions were similar between groups, except osteomyelitis and lower-limb amputations, both of which were less frequent in the Apligraf group. Trialists concluded that application of Apligraf for a maximum of 4 weeks resulted in higher healing rates than state-of-the-art treatment and was not associated with any significant adverse events. This trial was reviewed in a 2001 TEC Assessment, which concluded that Apligraf, in conjunction with good local wound care, met the TEC criteria for the treatment of diabetic ulcers that fail to respond to conservative management.(27)

Dermagraft

A 2003 pivotal multicenter FDA-regulated trial randomized 314 patients with chronic diabetic ulcers to Dermagraft (human-derived fibroblasts cultured on mesh) or control.(28) Over the 12-week study, patients received up to 8 applications of Dermagraft. All patients received pressure-reducing footwear and were encouraged to stay off their study foot as much as possible. At 12 weeks, the median percent wound closure for the Dermagraft group was 91% compared with 78% for the control group. Ulcers treated with Dermagraft closed significantly faster than ulcers treated with conventional therapy. No serious adverse events were attributed to Dermagraft. Ulcer infections developed in 10.4% of the Dermagraft patients compared with 17.9% of the control patients. Together, there was a lower rate of infection, cellulitis, and osteomyelitis in the Dermagraft-treated group (19% vs 32.5%). A 2015 retrospective analysis of the trial data found a significant reduction in amputation/bone resection rates with Dermagraft (5.5% vs 12.6%, $p=0.031$). (29) Of the 28 cases of amputation/bone resection, 27 were preceded by ulcer-related infection.

AlloPatch

AlloPatch Pliable human reticular acellular dermis was compared with SOC in an industry-sponsored multicenter trial by Zelen et al (2017-2018).(30,31) The initial trial, with 20 patients per group, was extended to determine the percent healing at 6 weeks with 40 patients per group. Healing was evaluated by the site investigator and confirmed by an independent panel. At six weeks, 68% (27/40) of wounds treated using AlloPatch had healed compared with 15% (6/40) in the SOC-alone group ($p<0.001$). At 12 weeks, 80% (32/40) of patients in the AlloPatch group had healed compared to 30% (12/40) in the control group. Mean time to heal within 12 weeks was 38 days (95% CI: 29 to 47 days) for the ADM group and 72 days (95% CI: 66 to 78 days) for the SOC group ($p < 0.001$).

Integra Omnigraft Dermal Regeneration Template or Integra Flowable Wound Matrix

Integra Dermal Regeneration Template is a biosynthetic skin substitute that is FDA-approved for life-threatening thermal injury. The FOUNDER (Foot Ulcer New Dermal Replacement)

multicenter study (32 sites) assessed Integra Dermal Regeneration Template (marketed as Omnigraft) for chronic nonhealing diabetic foot ulcers under an FDA-regulated investigational device exemption.(32) A total of 307 patients with at least 1 chronic diabetic foot ulcer were randomized to treatment with the Integra Template or a control condition (sodium chloride gel 0.9%). Treatment was given for 16 weeks or until wound closure. There was a modest increase in wound closure with the Integra Template (51% vs 32%, $p=0.001$) and a shorter median time to closure (43 days vs 78 days, $p=0.001$). There was a strong correlation between investigator-assessed and computerized planimetry assessment of wound healing ($r=0.97$). Kaplan-Meier analysis showed the greatest difference between groups in wound closure up to 10 weeks, with diminishing differences after 10 weeks. Trial strengths included adequate power to detect an increase in wound healing of 18%, which was considered to be clinically significant, secondary outcomes of wound closure and time to wound closure by computerized planimetry, and ITT analysis.

Integra Flowable Wound Matrix is composed of a porous matrix of cross-linked bovine tendon collagen and glycosaminoglycan. It is supplied as a granular product that is mixed with saline. Campitiello et al (2017) published an RCT that compared the flowable matrix with wet dressing in 46 patients who had Wagner grade 3 diabetic foot ulcers.(33) The ulcers had developed over 39 weeks. Complete healing at 6 weeks was achieved in significantly more patients in the Integra Flowable Wound Matrix group than in the control group, while the risk of rehospitalization and major amputation was reduced with Integra Flowable Wound Matrix (see Table 4).

Table 4. Probability of Wound Healing With IFWM vs SOC

Study	Complete Wound Healing	Rehospitalization	Major Amputation
Campitiello et al (2017)			
IFWM, n (%)	20 (86.95)	2 (6.69)	1 (4.34)
SOC, n (%)	12 (52.17)	10 (43.47)	7 (30.43)
RR (95% CI)	1.67 (1.09 to 2.54)	0.10 (0.01 to 0.72)	0.16 (0.02 to 1.17)
p	0.010	0.001	0.028

CI: confidence interval; IFWM: Integra Flowable Wound Matrix; RR: relative risk; SOC: standard of care.

mVASC

Tables 5 and 6 summarize the trial characteristics and results for RCTs of mVASC. Tables 7 and 8 evaluate study limitations.

Gould et al (2023) reported results of the HIFLO (Healing in Diabetic Foot Ulcers with Microvascular Tissue) Trial, a multicenter (6 US sites) RCT comparing weekly application of the processed microvascular tissue (PMVT) allograft, mVASC in addition to a standardized diabetic foot ulcer protocol versus standard wound care with a collagen alginate dressing control in 100 adults with Wagner Grade 1 and 2 diabetic foot ulcers of ≥ 4 weeks and < 52 weeks duration.(34) Wound and local peripheral neuropathy assessment were performed weekly. The primary outcome of the study was complete wound closure at 12 weeks. The investigator and a blinded physician made the initial determination of wound closure, followed by adjudication and confirmation by an independent, blinded panel of plastic surgeons. All participants who attended at least 1 treatment visit were included in the analysis. There was missing data for 15 participants at week 12 (3 in mVASC vs. 12 in control) and 14 of these were missing due to adverse events related to the wound. These were included in the primary analysis and counted as wound healing failures. The mean age of participants was 60 years, 90% of participants were White and 10% were Black, and 66% of participants were men. At

randomization, the mean size of the wound area was 3.3 cm and the mean duration of the wound was 15 weeks. The proportion of participants with complete wound closure at week 12 was 74% (37/50) for mVASC versus 38% (19/50) for control ($p<.001$). Of the wounds that healed, the mean time to healing was also statistically significantly faster for the mVASC group (54 days; 95% CI, 46 to 61 vs 64 days; 95% CI, 57 to 72; $p=.009$). The 10-point Semmes-Weinstein monofilament (SWM) test of peripheral neuropathy also favored mVASC (118% vs. 11%; $p=.028$). No adverse events or serious adverse events related to the study treatment or the procedure were reported. There were 11 adverse events (3, mVASC vs. 8, control) reported that were related to the wound.

Table 5. Randomized Controlled Trial of mVASC for Diabetic Foot Ulcers- Characteristics

Study	Countries	Sites	Dates	Participants	Interventions	
					Active	Comparator
Gould 2023; HIFLO	US	6	2017-2020	Adults with chronic Wagner Grade 1 or 2 DFU Mean age, 60 y 90% White 10% Black 66% Male Mean wound size 3.3 cm	mVASC + SOC (n=50)	SOC (n=50)

DFU: Diabetic Foot Ulcers; HIFLO: Healing in Diabetic Foot Ulcers with Microvascular Tissue; SOC: Standard of Care

Table 6. Randomized Controlled Trial of mVASC for Diabetic Food Ulcers- Results

Study	Wounds Healed	Time to Heal	% Area Reduction	Adverse events
Gould 2023; HIFLO	at 12 weeks	by 12 weeks	at 12 weeks	
N analyzed	100	56	100	100
mVASC	74% (37/50)	Mean, 54 d	76%	3
SOC	38% (19/50)	Mean, 64 d	24%	8
p-value	<.001	.009	.009	

DFU: Diabetic Foot Ulcers; HIFLO: Healing in Diabetic Foot Ulcers with Microvascular Tissue; SOC: Standard of Care

Table 7. Randomized Controlled Trial of mVASC for Diabetic Foot Ulcers- Study Relevance Limitations

Study	Population ^a	Intervention ^b	Comparator ^c	Outcomes ^d	Duration of Follow-up ^e
Gould 2023; HIFLO	4. Lack of racial and ethnic diversity				1. follow-up not sufficient to determine ulcer recurrence.

HIFLO: Healing in Diabetic Foot Ulcers with Microvascular Tissue

The study limitations stated in this table are those notable in the current review; this is not a comprehensive gaps assessment.

^a Population key: 1. Intended use population unclear; 2. Study population is unclear; 3. Study population not representative of intended use; 4. Enrolled populations do not reflect relevant diversity; 5. Other.

^b Intervention key: 1. Not clearly defined; 2. Version used unclear; 3. Delivery not similar intensity as comparator; 4. Not the intervention of interest (e.g., proposed as an adjunct but not tested as such); 5. Other.

^c Comparator key: 1. Not clearly defined; 2. Not standard or optimal; 3. Delivery not similar intensity as intervention; 4. Not delivered effectively; 5. Other.

^d Outcomes key: 1. Key health outcomes not addressed; 2. Physiologic measures, not validated surrogates; 3. Incomplete reporting of harms; 4. Not establish and validated measurements; 5. Clinically significant difference not prespecified; 6. Clinically significant difference not supported; 7. Other.

^e Follow-Up key: 1. Not sufficient duration for benefit; 2. Not sufficient duration for harms; 3. Other.

Table 8. Randomized Controlled Trial of mVASC for Diabetic Foot Ulcers- Study Design and Conduct Limitations

Study	Allocation ^a	Blinding ^b	Selective Reporting ^c	Data Completeness ^d	Power ^e	Statistical ^f
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Gould 2023; HIFLO	1. Registered retrospectively in European registry	3. Confidence intervals not reported
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HIFLO: Healing in Diabetic Foot Ulcers with Microvascular Tissue

The study limitations stated in this table are those notable in the current review; this is not a comprehensive gaps assessment.

^a Allocation key: 1. Participants not randomly allocated; 2. Allocation not concealed; 3. Allocation concealment unclear; 4.

Inadequate control for selection bias; 5. Other.

^b Blinding key: 1. Participants or study staff not blinded; 2. Outcome assessors not blinded; 3. Outcome assessed by treating physician; 4. Other.

^c Selective Reporting key: 1. Not registered; 2. Evidence of selective reporting; 3. Evidence of selective publication; 4. Other.

^d Data Completeness key: 1. High loss to follow-up or missing data; 2. Inadequate handling of missing data; 3. High number of crossovers; 4. Inadequate handling of crossovers; 5. Inappropriate exclusions; 6. Not intent to treat analysis (per protocol for noninferiority trials); 7. Other.

^e Power key: 1. Power calculations not reported; 2. Power not calculated for primary outcome; 3. Power not based on clinically important difference; 4. Other.

^f Statistical key: 1. Analysis is not appropriate for outcome type: (a) continuous; (b) binary; (c) time to event; 2. Analysis is not appropriate for multiple observations per patient; 3. Confidence intervals and/or p values not reported; 4. Comparative treatment effects not calculated; 5. Other

TheraSkin Versus Standard of Care

Tables 9 and 10 summarize the trial characteristics and results for RCTs of TheraSkin compared to SOC. Tables 11 and 12 evaluate study limitations.

Armstrong et al (2022) reported results of an RCT including 100 adults with non-healing Wagner 1 diabetic foot ulcers comparing TheraSkin (n=50) to SOC (n=50).⁽³⁵⁾ The index ulcer had to have been present for greater than 4 weeks and less than 1 year with a minimum size of 1.0 cm² and a maximum size of 25 cm². Standard of care included glucose monitoring, weekly debridement as appropriate, and an offloading device. The dressing in the SOC group was calcium alginate (Fibracol Plus). The primary outcome was the proportion of full-thickness wounds healed at 12 weeks. Wound healing was assessed initially by the investigator and confirmed by blinded adjudication panel. Wounds were closed when there was 100% re-epithelization and no drainage. The mean age of participants was 60 years; 53% of participants were male, 70% were White, and 15% were Black. The mean wound area at baseline was 4.1 cm². Participants who did not have healing of at least 50% by 6 weeks were allowed to seek alternative rescue wound care (TheraSkin, n=1; SOC, n=11). In addition, 3 participants in the TheraSkin group and 8 in the SOC group had worsening of the wound or an adverse event before week 12. All enrolled participants were included in analysis and missing data were imputed using last observation carried forward. The percent of participants with complete wound healing at week 12 was 76% (38/50) in the intervention group compared with 36% (18/50) in the SOC group (p<.01). The mean percent area reduction at 12 weeks was 77.8% in the TheraSkin group compared with 49.6% in the SOC group (p<.01). There were no statistically significant differences between groups in QOL or pain score measures.

Table 9. Randomized Controlled Trial of TheraSkin vs. SOC for Diabetic Foot Ulcers- Characteristics

Study	Countries	Sites	Dates	Participants	Interventions	
					Active	Comparator
Armstrong (2022); NCT04040426	US	5	2019- 2021	Adults with non-healing Wagner 1 DFUs	TheraSkin (n=50)	SOC with calcium alginate dressing (n=50)
				Mean wound area, 4.1 cm ²		
				Mean age, 60 yrs		
				53% male		
				70% White		
				15% Black		

Table 10. Randomized Controlled Trial of TheraSkin vs. SOC for Diabetic Foot Ulcers- Results

Study	Wounds Healed at 12 weeks	Time to Heal by 12 weeks	% Area Reduction at 12 weeks	Adverse events
Armstrong (2022); NCT04040426				
N analyzed	100	100	100	100
TheraSkin	76% (38/50)	Mean, 47 days (95% CI, 39 to 55)	78% (SD=63)	2
SOC	36% (18/50)	Mean, 65 days (95% CI, 58 to 73)	50% (SD=98)	4
-value	<.01	<.01	<.01	NR

CI: confidence interval; NR: not reported; SD: standard deviation; SOC: standard of care

Table 11. Randomized Controlled Trial of TheraSkin vs. SOC for Diabetic Foot Ulcers- Study Relevance Limitations

Study	Population ^a	Intervention ^b	Comparator ^c	Outcomes ^d	Duration of Follow-up ^e
Armstrong (2022); NCT04040426	4. Lack of racial and ethnic diversity				1. follow-up not sufficient to determine ulcer recurrence.

SOC: standard of care.

The study limitations stated in this table are those notable in the current review; this is not a comprehensive gaps assessment.

^a Population key: 1. Intended use population unclear; 2. Study population is unclear; 3. Study population not representative of intended use; 4. Enrolled populations do not reflect relevant diversity; 5. Other.^b Intervention key: 1. Not clearly defined; 2. Version used unclear; 3. Delivery not similar intensity as comparator; 4. Not the intervention of interest (e.g., proposed as an adjunct but not tested as such); 5. Other.^c Comparator key: 1. Not clearly defined; 2. Not standard or optimal; 3. Delivery not similar intensity as intervention; 4. Not delivered effectively; 5. Other.^d Outcomes key: 1. Key health outcomes not addressed; 2. Physiologic measures, not validated surrogates; 3. Incomplete reporting of harms; 4. Not establish and validated measurements; 5. Clinically significant difference not prespecified; 6. Clinically significant difference not supported; 7. Other.^e Follow-Up key: 1. Not sufficient duration for benefit; 2. Not sufficient duration for harms; 3. Other.**Table 12. Randomized Controlled Trial of TheraSkin vs. SOC for Diabetic Foot Ulcers- Study Design and Conduct Limitations**

Study	Allocation ^a	Blinding ^b	Selective Reporting ^c	Data Completeness ^d	Power ^e	Statistical ^f
Armstrong (2022); NCT04040426		1. Investigators not blinded		2. Missing data imputed by last observation carried forward; no sensitivity analyses provided		

SOC: standard of care.

The study limitations stated in this table are those notable in the current review; this is not a comprehensive gaps assessment.

^a Allocation key: 1. Participants not randomly allocated; 2. Allocation not concealed; 3. Allocation concealment unclear; 4. Inadequate control for selection bias; 5. Other.^b Blinding key: 1. Participants or study staff not blinded; 2. Outcome assessors not blinded; 3. Outcome assessed by treating physician; 4. Other.^c Selective Reporting key: 1. Not registered; 2. Evidence of selective reporting; 3. Evidence of selective publication; 4. Other.^d Data Completeness key: 1. High loss to follow-up or missing data; 2. Inadequate handling of missing data; 3. High number of crossovers; 4. Inadequate handling of crossovers; 5. Inappropriate exclusions; 6. Not intent to treat analysis (per protocol for noninferiority trials); 7. Other.^e Power key: 1. Power calculations not reported; 2. Power not calculated for primary outcome; 3. Power not based on clinically important difference; 4. Other.^f Statistical key: 1. Analysis is not appropriate for outcome type: (a) continuous; (b) binary; (c) time to event; 2.

Analysis is not appropriate for multiple observations per patient; 3. Confidence intervals and/or p values not reported; 4. Comparative treatment effects not calculated; 5. Other

TheraSkin Versus Dermagraft

Sanders et al (2014) reported on an (N=23) industry-funded randomized comparison of TheraSkin (cryopreserved human skin allograft with living fibroblasts and keratinocytes) and Dermagraft for diabetic foot ulcers.(36) Wound size at baseline ranged from 0.5 to 18.02 cm²; the average wound size was about 5 cm² and was similar for the 2 groups (p=.51). Grafts were applied according to manufacturers' instructions over the first 12 weeks of the study until healing, with an average of 4.4 TheraSkin grafts (every 2 weeks) compared with 8.9 Dermagraft applications (every week). At week 12, complete wound healing was observed in 63.6% of ulcers treated with TheraSkin and 33.3% of ulcers treated with Dermagraft (p<.049). At 20 weeks, complete wound healing was observed in 90.9% of the TheraSkin-treated ulcers compared with 66.7% of the Dermagraft group (p=.428).

TheraSkin Versus Apligraf

DiDomenico et al (2011) compared TheraSkin with Apligraf for the treatment of diabetic foot ulcers in a (N=29) RCT.(37) The risk of bias in this study is uncertain because reporting did not include a description of power analysis, statistical analysis, method of randomization, or blinding. The percentage of wounds closed at 12 weeks was 41.3% in the Apligraf group and 66.7% in the TheraSkin group. Results at 20 weeks were not substantially changed from those at 12 weeks, with 47.1% of wounds closed in the Apligraf group and 66.7% closed in the TheraSkin group. The percentage healed in the Apligraf group was lower than expected based on prior studies. The average number of grafts applied was similar for both groups (1.53 for Apligraf, 1.38 for TheraSkin). The low number of dressing changes may have influenced results, with little change in the percentage of wounds closed between 12 and 20 weeks. An adequately powered trial with blinded evaluation of wound healing and a standard treatment regimen would permit greater certainty on the efficacy of this product.

Section Summary: Apligraf, Dermagraft, AlloPatch, Integra, mVASC, or TheraSkin for Diabetic Lower-Extremity Ulcers

RCTs reporting complete wound healing outcomes with at least 12 weeks of follow-up have demonstrated the efficacy of Apligraf, Dermagraft, AlloPatch, Integra Dermal Regeneration Template, Integra Flowable Wound Matrix, mVASC and TheraSkin over SOC for the treatment of diabetic lower-extremity ulcers.

Bioengineered Skin Substitutes Other Than Apligraf, Dermagraft, AlloPatch, Integra, mVASC, or TheraSkin

Graftjacket Regenerative Tissue Matrix

Brigido et al (2004) reported a (N=40) randomized pilot study comparing Graftjacket with conventional treatment for chronic nonhealing diabetic foot ulcers.(38) Control patients received conventional therapy with débridement, wound gel with gauze dressing, and off-loading. Graftjacket patients received surgical application of the scaffold using skin staples or sutures and moistened compressive dressing. A second graft application was necessary after the initial application for all patients in the Graftjacket group. Preliminary one month results showed that, after a single treatment, ulcers treated with Graftjacket healed at a faster rate than conventional treatment. There were significantly greater decreases in wound length (51% vs 15%), width (50% vs 23%), area (73% vs 34%), and depth (89% vs 25%), respectively. With follow-up to four weeks, no data were reported on the proportion with complete closure or the mean time to heal. All grafts were incorporated into the host tissue.

Reyzelman et al (2009) reported an industry-sponsored multicenter randomized study that compared a single application of Graftjacket with SOC in 86 patients with diabetic foot ulcers.(39) Eight patients, 6 in the study group and 2 in the control group, did not complete the trial. At 12 weeks, complete healing was observed in 69.6% of the Graftjacket group and 46.2% of controls. After adjusting for ulcer size at presentation, a statistically significant difference in nonhealing rate was calculated, with odds of healing 2.0 times higher in the study group. Mean healing time was 5.7 weeks for the Graftjacket group vs 6.8 weeks for the control group. The authors did not report whether this difference was statistically significant. Median time to healing was 4.5 weeks for Graftjacket (range, 1 to 12 weeks) and 7.0 weeks for control (range, 2 to 12 weeks). Kaplan-Meier method survivorship analysis for time to complete healing at 12 weeks showed a significantly lower nonhealing rate for the study group (30.4%) than for the control group (53.9%). The authors commented that a single application of Graftjacket, as used in this study, was often sufficient for complete healing.

Reyzelman and Bazarov (2015) (40) reported an industry-sponsored meta-analysis of Graftjacket for diabetic foot ulcers that included the two studies described above and a third RCT by Brigido (2006) (41) with 28 patients (N=154). The time to heal was estimated for the 2004 Brigido study, based on the average wound reduction per week. The estimated difference in time to heal was considerably larger for Brigido's 2004 study (-4.30 weeks) than for the other 2 studies that measured the difference in time to heal (-1.58 weeks and -1.10 weeks). Analysis of the proportion of wounds that healed included Brigido (2006) and Reyzelman et al (2009). The odds ratio in the smaller study by Brigido was considerably larger, with a lack of precision in the estimate (odds ratio, 15.0; 95% CI, 2.26 to 99.64), and the combined odds (3.75; 95% CI, 1.72 to 8.19) was not significant when analyzed using a random-effects model. Potential sources of bias, noted by Reyzelman and Bazarov, included publication and reporting biases, study selection biases, incomplete data selection, post hoc manipulation of data, and subjective choice of analytic methods. Overall, results of these studies do not provide convincing evidence that Graftjacket is more effective than SOC for healing diabetic foot ulcers.

DermACELL vs Graftjacket Regenerative Tissue Matrix or SOC

DermACELL and Graftjacket are both composed of human ADM. Walters et al (2016) reported on a multicenter randomized comparison of DermACELL, Graftjacket, or SOC (2:1:2 ratio) in 168 patients with diabetic foot ulcers.(42) The study was sponsored by LifeNet Health, a nonprofit organ procurement association and processor for DermACELL. At 16 weeks, the proportion of completely healed ulcers was 67.9% for DermACELL, 47.8% for Graftjacket, and 48.1% for SOC. The 20% difference in completely healed ulcers was statistically significant for DermACELL vs SOC (p=0.039). The mean time to complete wound closure did not differ significantly for DermACELL (8.6 weeks), Graftjacket (8.6 weeks), and SOC (8.7 weeks).

A second report from this study was published in 2017.(43) This analysis compared DermACELL with SOC and did not include the Graftjacket arm. The authors reported that either 1 or 2 applications of DermACELL led to a greater proportion of wounds healed compared with SOC in per protocol analysis (see Table 13), but there was no significant difference between DermACELL (1 or 2 applications) and SOC when analyzed by intention-to-treat. For the group of patients who received only a single application, the percentage of patients who achieved complete wound healing was significantly higher than SOC at 16 and 24 weeks, but not at 12 weeks. Although reported as an ITT analysis, results were analyzed only for the group who received a single application of DermACELL. This would not typically be considered ITT.

Table 13. Probability of Wound Healing in Per Protocol Analysis of DermACELL vs SOC

Study	Single Application			One or Two Applications		
	% With Wound Healing at 12 Wk	% With Wound Healing at 16 Wk	% With Wound Healing at 24 Wk	% With Wound Healing at 12 Wk	% With Wound Healing at 16 Wk	% With Wound Healing at 24 Wk
Cazzell et al (2017)						
DermACELL, %	65.0%	82.5%	89.7%	NR	67.9%	83.7%
SOC, %	41.1%	48.1%	67.3%	NR	48.1%	67.3%
HR (95% CI)	1.97 (1.1 to 3.5)	2.40 (1.4 to 4.1)	2.11 (1.3 to 3.5)		1.72 (1.04 to 2.83)	1.55 (0.98 to 2.44)
p	0.012	<0.001	<0.001	NS	0.028	0.049

CI: confidence interval; HR: hazard ratio; NR: not reported; NS: not significant; SOC: standard of care.

Cytal (MatriStem) vs Dermagraft

Frykberg et al (2017) reported a prespecified interim analysis of an industry-funded multicenter noninferiority trial of Cytal (a porcine urinary bladder-derived extracellular matrix) vs Dermagraft in 56 patients with diabetic foot ulcers.(44) The mean duration of ulcers before treatment was 263 days (range, 30 to 1095 days). The primary outcome was the percent wound closure with up to 8 weeks of treatment which used blind evaluations of photographs. Intention-to-treat (ITT) analysis found complete wound closure in 5 (18.5%) wounds treated with Cytal compared with two (6.9%) wounds treated with Dermagraft (p =not significant [NS]). Quality of life (QOL), measured by the Diabetic Foot Ulcer Scale, improved from 181.56 to 151.11 in the Cytal group and from 184.46 to 195.73 in the Dermagraft group (p =0.074). It should be noted that this scale is a subjective measure and patients were not blinded to treatment. Power analysis indicated that 92 patients would be required; further recruitment is ongoing for completion of the study.

PriMatrix

Lantis et al (2021) reported on a multicenter RCT comparing PriMatrix plus standard of care to PriMatrix alone in 226 patients with diabetic foot ulcers (Tables 14 and 15).(45)

Study subjects underwent a 2-week run-in period of SOC treatment and were excluded if they had a wound reduction of 30% or more. Patients randomized to the SOC group received weekly treatment at the study site identical to the SOC treatment applied during the screening period. In addition, control group patients performed daily dressing changes, which consisted of wound cleaning, application of saline gel and secondary dressings. The primary endpoint was the percentage of subjects with complete wound closure, defined as 100% re-epithelialization without drainage during the 12-week treatment phase.

Significantly more patients in the PriMatrix group experienced complete wound closure at 12 weeks (45.6% vs 27.9%; p =.008). It is unclear if this difference (17.7%) is clinically significant; the study was powered to detect a 20% difference between groups. The time to complete healing did not differ between groups for the wounds that healed. Major study limitations include lack of blinding, limited generalizability, and insufficient duration of follow-up to assess wound recurrence (Tables 16 and 17).

Table 14. Randomized Controlled Trial of PriMatrix for Diabetic Foot Ulcers- Characteristics

Study	Countries	Sites	Dates	Participants	Interventions	
					Active	Comparator

Lantis et al (2021) NCT03010319	US	21	2019-2020	Diabetic foot ulcer for a minimum of 2 weeks, adequate vascular perfusion to the affected extremity	PriMatrix plus standard of care n = 103	Standard of care n = 104
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Table 15. Randomized Controlled Trial of PriMatrix for Diabetic Foot Ulcers- Results

Study	Wound Healed at 12 weeks	Median Time to Heal, days (range)	AEs
Lantis et al (2021) NCT03010319			
Number analyzed	207	76	226
Primatrix	47/103 (45.6%)	43 (22 to 93)	Any AE: 44.8%
Standard Care	29/104 (27.9%)	57 (16 to 88)	Any AE: 46.4%
Treatment Effect	HR 2.02 (95% CI 1.3 to 3.2)		
p	.008	0.362	

AE: adverse events; CI: confidence interval; HR: hazard ratio

Table 16. Randomized Controlled Trial of PriMatrix for Diabetic Foot Ulcers- Study Relevance Limitations

Study	Population ^a	Intervention ^b	Comparator ^c	Outcomes ^d	Duration of Follow-up ^e
Lantis et al (2021) NCT03010319	4. Race and ethnicity of the study population was not reported and is not included in the demographics table.		3. Standard of care patients received additional dressing changes at home, which could have potentially exposed the wound to unknown factors.		4-week follow-up not sufficient to determine ulcer recurrence.

The study limitations stated in this table are those notable in the current review; this is not a comprehensive gaps assessment.

^a Population key: 1. Intended use population unclear; 2. Study population is unclear; 3. Study population not representative of intended use; 4. Enrolled populations do not reflect relevant diversity; 5. Other.

^b Intervention key: 1. Not clearly defined; 2. Version used unclear; 3. Delivery not similar intensity as comparator; 4. Not the intervention of interest (e.g., proposed as an adjunct but not tested as such); 5. Other.

^c Comparator key: 1. Not clearly defined; 2. Not standard or optimal; 3. Delivery not similar intensity as intervention; 4. Not delivered effectively; 5. Other.

^d Outcomes key: 1. Key health outcomes not addressed; 2. Physiologic measures, not validated surrogates; 3. Incomplete reporting of harms; 4. Not establish and validated measurements; 5. Clinically significant difference not prespecified; 6. Clinically significant difference not supported; 7. Other.

^e Follow-Up key: 1. Not sufficient duration for benefit; 2. Not sufficient duration for harms; 3. Other.

Table 17. Randomized Controlled Trial of PriMatrix for Diabetic Foot Ulcers- Study Design and Conduct Limitations

Study	Allocation ^a	Blinding ^b	Selective Reporting ^c	Data Completeness ^d	Power ^e	Statistical ^f
Lantis et al (2021) NCT03010319	3. Allocation concealment not described.	1. Patients and investigator not blinded		1. 24 subjects from the treatment group and 22 from the control group discontinued from each arm prior to meeting the protocol-defined primary endpoint and were counted as treatment failures. 207 of 226 randomized were included in primary analysis (91.6%)		3. Confidence intervals not reported

The study limitations stated in this table are those notable in the current review; this is not a comprehensive gaps assessment.

^a Allocation key: 1. Participants not randomly allocated; 2. Allocation not concealed; 3. Allocation concealment unclear; 4.

Inadequate control for selection bias; 5. Other.

^b Blinding key: 1. Participants or study staff not blinded; 2. Outcome assessors not blinded; 3. Outcome assessed by treating physician; 4. Other.

^c Selective Reporting key: 1. Not registered; 2. Evidence of selective reporting; 3. Evidence of selective publication; 4. Other.

^d Data Completeness key: 1. High loss to follow-up or missing data; 2. Inadequate handling of missing data; 3. High number of crossovers; 4. Inadequate handling of crossovers; 5. Inappropriate exclusions; 6. Not intent to treat analysis (per protocol for noninferiority trials); 7. Other.

^e Power key: 1. Power calculations not reported; 2. Power not calculated for primary outcome; 3. Power not based on clinically important difference; 4. Other.

^f Statistical key: 1. Analysis is not appropriate for outcome type: (a) continuous; (b) binary; (c) time to event; 2. Analysis is not appropriate for multiple observations per patient; 3. Confidence intervals and/or p values not reported; 4. Comparative treatment effects not calculated; 5. Other

Oasis Wound Matrix vs Regranex Gel

Niezgoda et al (2005) compared healing rates at 12 weeks for full-thickness diabetic foot ulcers treated with OASIS Wound Matrix (a porcine acellular wound care product) to Regranex Gel.(46) This industry-sponsored, multicenter RCT was conducted at 9 outpatient wound care clinics and involved 73 patients with at least 1 diabetic foot ulcer. Patients were randomized to receive either Oasis Wound Matrix (n=37) or Regranex Gel (n=36) and a secondary dressing. Wounds were cleansed and débrided, if needed, at a weekly visit. The maximum treatment period for each patient was 12 weeks. After 12 weeks, 18 (49%) Oasis-treated patients had complete wound closure compared with 10 (28%) Regranex-treated patients. Oasis treatment met the noninferiority margin but did not demonstrate that healing in the Oasis group was statistically superior (p=0.055). Post hoc subgroup analysis showed no significant difference in incidence of healing in patients with Type I diabetes (33% vs 25%) but showed a significant improvement in patients with Type II diabetes (63% vs 29%). There was also increased healing of plantar ulcers in the Oasis group (52% vs 14%). These post hoc findings are considered hypothesis-generating. Additional study with a larger number of subjects is needed to compare the effect of Oasis treatment to current SOC.

Autologous Grafting on HYAFF Scaffolds

Uccioli et al (2011) reported a multicenter RCT of cultured expanded fibroblasts and keratinocytes grown on a HYAFF scaffold (benzyl ester of hyaluronic acid) compared with paraffin gauze for difficult diabetic foot ulcers.(47) A total of 180 patients were randomized. At 12 weeks, complete ulcer healing was similar for the two groups (24% treated vs 21% controls). At 20 weeks, complete ulcer healing was achieved in a similar proportion of the treatment group (50%) and the control group (43%, log-rank test = 0.344). Subgroup analysis, adjusted for baseline factors and possibly post-hoc, found a statistically significant benefit of treatment on dorsal ulcers but not plantar ulcers.

Kerecis Omega3 Wound

Lullove et al (2022) reported interim results and Lantis et al (2023) reported the final results of a RCT of the Omega3 Wound (Kerecis) plus standard wound care compared to standard care alone in individuals with diabetic lower extremity skin ulcers (Tables 18).(48,49,50) The primary outcome of the trial was healing at 12 weeks. Complete ulcer healing was based on the site investigator's assessment, as evidenced by complete (100%) re-epithelialization without drainage and need of dressing. An independent panel of wound care experts who were blinded to the patient allocation process and the principal investigator's assessment reviewed all study-related decisions made by the site investigators and confirmed healing status. Secondary outcomes were time to heal and wound area reduction by percentage at 12 weeks. Patients underwent a 2-week run-in period prior to randomization. If the ulcer area reduced by 20% or more after 14 days of standard care, the patient was excluded as a screening failure. If

the wound area was reduced by less than 20%, the patient was randomized and enrolled in the study.

Study results are summarized in Table 19. At 12 weeks, the complete healing rate was significantly higher in the intervention arm (57% vs 31%), but time to healing did not differ between groups for wounds that healed completely. Among the subset of wounds that did not heal completely by 12 weeks (n = 65), there was a larger percent wound reduction in the intervention group (86% vs 64%; p =.03). Of the 45 participants whose wound healed during the 12 weeks of the trial, 42 were available for follow-up 6 to 12 months following healing. 3 (11%) ulcer recurrences were reported in the intervention arm compared to 1 (7%) in the control arm.

Study limitations are detailed in Tables 20 and 21. Notably, 2 larger RCTs are registered and reported as completed but have not been published.

Table 18. Randomized Controlled Trial of Omega3 Wound for Diabetic Foot Ulcers- Characteristics

Study; Trial	Countries	Sites	Dates	Participants	Interventions	
					<i>Active</i>	<i>Comparator</i>
Lantis et al (2023)	US	16	2019-2022	Diabetic foot ulcer for a minimum of 4 weeks, adequate renal function and perfusion to the affected extremity	Omega3 Wound plus standard of care (n=51)	Standard of care (n=51)
Lullove et al (2021)						
NCT04133493				Mean age, 60y 69% Men 80% White 7% Black		
				Mean wound size, 4.4 cm		

Table 19. Randomized Controlled Trial of Omega3 Wound for Diabetic Foot Ulcers- Results

Study	Wound Healed at 12 weeks	Time to Heal	Percent Wound Reduction at 12 Weeks for Wounds that did not Heal	Adverse events
Lantis et al (2023) Lullove et al (2021)				
NCT04133493				
N analyzed	102		65	
Omega3 Wound	57% (29/51)			
Standard Care	31% (16/51)	Mean 7 weeks in both groups		5
p	0.02		0.03	

Table 20. Randomized Controlled Trial of Omega3 Wound for Diabetic Foot Ulcers- Study Relevance Limitations

Study	Population ^a	Intervention ^b	Comparator ^c	Outcomes ^d	Duration of Follow-up ^e
Lantis et al (2023)	4. Lack of racial and ethnic diversity		3. Standard of care patients received additional dressing changes at home, which could have potentially exposed the wound to unknown factors.		
Lullove et al (2021) ⁵²					
NCT04133493					

The study limitations stated in this table are those notable in the current review; this is not a comprehensive gaps assessment.

^a Population key: 1. Intended use population unclear; 2. Study population is unclear; 3. Study population not representative of intended use; 4. Enrolled populations do not reflect relevant diversity; 5. Other.

^b Intervention key: 1. Not clearly defined; 2. Version used unclear; 3. Delivery not similar intensity as comparator; 4. Not the intervention of interest (e.g., proposed as an adjunct but not tested as such); 5. Other.

^c Comparator key: 1. Not clearly defined; 2. Not standard or optimal; 3. Delivery not similar intensity as intervention; 4. Not delivered effectively; 5. Other.

^d Outcomes key: 1. Key health outcomes not addressed; 2. Physiologic measures, not validated surrogates; 3. Incomplete reporting of harms; 4. Not establish and validated measurements; 5. Clinically significant difference not prespecified; 6. Clinically significant difference not supported; 7. Other.

^e Follow-Up key: 1. Not sufficient duration for benefit; 2. Not sufficient duration for harms; 3. Other.

Table 21. Randomized Controlled Trial of Omega3 Wound for Diabetic Foot Ulcers- Study Design and Conduct Limitations

Study	Allocation ^a	Blinding ^b	Selective Reporting ^c	Data Completeness ^d	Power ^e	Statistical ^f
Lantis et al (2023)			3. Two larger RCTs are reported as completed on clinicaltrials.gov but have not been published (NCT04257370 and NCT04537520)	1, 2. 25% of participants did not complete week 12. Although they were included in the primary ITT analysis, the method of imputation was unclear.		3. Confidence intervals not reported
Lullove et al (2021) NCT04133493						

ITT: intention-to-treat; RCT: randomized controlled trial.

The study limitations stated in this table are those notable in the current review; this is not a comprehensive gaps assessment.

^a Allocation key: 1. Participants not randomly allocated; 2. Allocation not concealed; 3. Allocation concealment unclear; 4.

Inadequate control for selection bias; 5. Other.

^b Blinding key: 1. Participants or study staff not blinded; 2. Outcome assessors not blinded; 3. Outcome assessed by treating physician; 4. Other.

^c Selective Reporting key: 1. Not registered; 2. Evidence of selective reporting; 3. Evidence of selective publication; 4. Other.

^d Data Completeness key: 1. High loss to follow-up or missing data; 2. Inadequate handling of missing data; 3. High number of crossovers; 4. Inadequate handling of crossovers; 5. Inappropriate exclusions; 6. Not intent to treat analysis (per protocol for noninferiority trials); 7. Other.

^e Power key: 1. Power calculations not reported; 2. Power not calculated for primary outcome; 3. Power not based on clinically important difference; 4. Other.

^f Statistical key: 1. Analysis is not appropriate for outcome type: (a) continuous; (b) binary; (c) time to event; 2. Analysis is not appropriate for multiple observations per patient; 3. Confidence intervals and/or p values not reported; 4. Comparative treatment effects not calculated; 5. Other

Section Summary: Bioengineered Skin Substitutes Other Than Apligraf, Dermagraft, AlloPatch, or Integra for Diabetic Lower-Extremity Ulcers

Results from a multicenter RCT showed some benefit of DermACELL that was primarily for the subgroup of patients who only required a single application of the ADM. Studies are needed to further define the population who might benefit from this treatment. Additional study with a larger number of subjects is needed to evaluate the effect of Graftjacket, DermACELL, Cytal, PriMatrix, and Oasis Wound Matrix, compared with current SOC or other advanced wound therapies. Keresis has RCTs that are reported as completed on clinicaltrials.gov but which have not been published (NCT04257370 and NCT04537520).

LOWER-EXTREMITY ULCERS DUE TO VENOUS INSUFFICIENCY

Apligraf

Falanga et al (1998) reported on a multicenter randomized trial of Apligraf living cell therapy.(52) A total of 293 patients with venous insufficiency and clinical signs of venous ulceration were randomized to compression therapy alone or to compression therapy and treatment with Apligraf. Apligraf was applied up to a maximum of 5 (mean, 3.3) times per

patient during the initial three weeks. The primary end points were the percentage of patients with complete healing by six months after initiation of treatment and the time required for complete healing. At six-month follow-up, the percentage of patients healed was higher with Apligraf (63% vs 49%), and the median time to complete wound closure was shorter (61 days vs 181 days). Treatment with Apligraf was superior to compression therapy in healing larger (>1000 mm²) and deeper ulcers and ulcers of more than 6 months in duration. There were no symptoms or signs of rejection, and the occurrence of adverse events was similar in both groups. This study was reviewed in a 2001 TEC Assessment, which concluded that Apligraf (Graftskin), in conjunction with good local wound care, met TEC criteria for the treatment of venous ulcers that fail to respond to conservative management.(27)

Oasis Wound Matrix

Mostow et al (2005) reported on an industry-sponsored multicenter (12 sites) randomized trial that compared weekly treatment using Oasis Wound Matrix (xenogeneic collagen scaffold from porcine small intestinal mucosa) with SOC in 120 patients who had chronic ulcers due to venous insufficiency that had not adequately responding to conventional therapy.(53) Healing was assessed weekly for up to 12 weeks, with follow-up performed after six months to assess recurrence. After 12 weeks of treatment, there was a significant improvement in the percentage of wounds healed in the Oasis group (55% vs 34%). After adjusting for baseline ulcer size, patients in the Oasis group were three times more likely to heal than those in the group receiving SOC. Patients in the SOC group whose wounds did not heal by week 12 were allowed to cross over to Oasis treatment. None of the healed patients treated with Oasis wound matrix who was seen for the 6-month follow-up experienced ulcer recurrence.

A research group in Europe has described two comparative studies of the Oasis matrix for mixed arteriovenous ulcers. In a 2007 quasi randomized study, Romanelli et al compared the efficacy of two extracellular matrix-based products, Oasis and Hyaloskin (extracellular matrix with hyaluronic acid).(54) Fifty-four patients with mixed arteriovenous leg ulcers were assigned to the two arms based on order of entry into the study; 50 patients completed the study. Patients were followed twice weekly, and dressings changed more than once a week, only when necessary. After 16 weeks of treatment, complete wound closure was achieved in 82.6% of Oasis-treated ulcers compared with 46.2% of Hyaloskin-treated ulcers. Oasis treatment significantly increased the time to dressing change (mean, 6.4 days vs 2.4 days), reduced pain on a 10-point scale (3.7 vs 6.2), and improved patient comfort (2.5 vs 6.7).

Romanelli et al (2010) compared Oasis with a moist wound dressing (SOC) in 23 patients with mixed arteriovenous ulcers and 27 patients with venous ulcers.(55) The trial was described as randomized, but the method of randomization was not described. After the 8-week study period, patients were followed monthly for six months to assess wound closure. Complete wound closure was achieved in 80% of the Oasis-treated ulcers at eight weeks compared with 65% of the SOC group. On average, Oasis-treated ulcers achieved complete healing in 5.4 weeks compared with 8.3 weeks for the SOC group. Treatment with Oasis also increased the time between dressing changes (5.2 days vs 2.1 days) and the percentage of granulation tissue formed (65% vs 38%).

Section Summary: Apligraf or Oasis Wound Matrix for Lower-Extremity Ulcers due to Venous Insufficiency

RCTs have demonstrated the efficacy of Apligraf or Oasis Wound Matrix over SOC for lower-extremity ulcers due to venous insufficiency.

Bioengineered Skin Substitutes Other Than Apligraf or Oasis Wound Matrix for Lower-Extremity Ulcers due to Venous Insufficiency

Dermagraft

Dermagraft living cell therapy has been approved by FDA for repair of diabetic foot ulcers. Use of Dermagraft for venous ulcers is an off-label indication. Harding et al (2013) reported an open-label multicenter RCT that compared Dermagraft plus compression therapy (n=186) with compression therapy alone (n=180).(56) The trial had numerous inclusion and exclusion criteria that restricted the population to patients who had nonhealing ulcers with compression therapy but had the capacity to heal. ITT analysis revealed no significant difference between the two groups in the primary outcome measure, the proportion of patients with completely healed ulcers by 12 weeks (34% Dermagraft vs 31% control). Prespecified subgroup analysis revealed a significant improvement in the percentage of wounds healed for ulcers of 12 months or less in duration (52% vs 37%) and for ulcers of 10 cm or less in diameter (47% vs 39%). There were no significant differences in the secondary outcomes of time to healing, complete healing by week 24, and percent reduction in ulcer area.

DermACELL

Cazzell (2019) published an RCT on DermACELL ADM for venous leg ulcers in 18 patients (see Table 22).(57) This was part of a larger study of the acellular dermal matrix for chronic wounds of the lower extremity in 202 patients; the component on diabetic lower extremity ulcers was previously reported by Cazzell et al (2017) and is described above.(40) When including patients who required more than one application of the ADM, the percent of wounds closed at 24 weeks was 29.4% with DermACELL and 33.3% with SOC, suggesting no benefit DermACELL for the treatment of venous ulcers in this small sub study.

Table 22. Summary of Key RCT Characteristics

Study; Trial	Countries	Sites	Dates	Participants	Interventions	
					Active	Comparator
Cazzell (2019) NCT01970163	US	7	2013- 2016	Venous leg ulcer present for at least 60 days (n=18)	1 or 2 applications of DermACELL plus SOC (n=18)	SOC (debridement and compression, n=10)

RCT: randomized controlled trial; SOC: standard of care

Section Summary: Bioengineered Skin Substitutes Other Than Apligraf or Oasis Wound Matrix for Lower-Extremity Ulcers due to Venous Insufficiency

In a moderately large RCT, Dermagraft was not shown to be more effective than controls in the primary or secondary end points for the entire population and was slightly more effective than controls (an 8% to 15% increase in healing) only in subgroups of patients with ulcer duration of 12 months or less or wound diameter of 10 cm or less.

DEEP DERMAL BURNS

Epicel

One case series from 2000 has described the treatment of 30 severely burned patients with Epicel.(58) The cultured epithelial autografts were applied to a mean of 37% of total body surface area (TBSA). Epicel achieved permanent coverage of a mean of 26% of TBSA, an area similar to that covered by conventional autografts (mean, 25%). Survival was 90% in these severely burned patients.

Integra Dermal Regeneration Template

A 2013 study compared Integra with split-thickness skin graft and with viscose cellulose sponge (Cellonex), using three 10x5 cm test sites on each of 10 burn patients.(59) The surrounding burn area was covered with meshed autograft. Biopsies were taken from each site on days 3, 7, 14, and 21, and at months 3 and 12. The tissue samples were stained and examined for markers of inflammation and proliferation. The Vancouver Scar Scale was used to assess scars. At 12-month follow-up, the three methods resulted in similar clinical appearance, along with similar histologic and immunohistochemical findings.

Branski et al (2007) reported on a randomized trial that compared Integra with a standard autograft-allograft technique in 20 children with an average burn size of 73% TBSA (71% full-thickness burns).(60) Once vascularized (about 14 to 21 days), the Silastic epidermis was stripped and replaced with thin (0.05 to 0.13 mm) epidermal autograft. There were no significant differences between the Integra group and controls in burn size (70% vs 74% TBSA), mortality (40% vs 30%), and hospital length of stay (41 vs 39 days), all respectively. Long-term follow-up revealed a significant increase in bone mineral content and density (24 months) and improved scarring in terms of height, thickness, vascularity, and pigmentation (at 12 months and 18-24 months) in the Integra group. No differences were observed between groups in the time to first reconstructive procedure, cumulative reconstructive procedures required for 2 years, and cumulative operating room time required for these procedures. The authors concluded that Integra can be used for immediate wound coverage in children with severe burns without the associated risks of cadaver skin.

Heimbach et al (2003) reported on a multicenter (13 U.S. burn care facilities) post-approval study involving 222 burn injury patients (36.5% TBSA; range, 1% to 95%) who were treated with Integra Dermal Regeneration Template.(61) Within 2 to 3 weeks, the dermal layer regenerated, and a thin epidermal autograft was placed over the wound. The incidence of infection was 16.3%. Mean take rate (absence of graft failure) of Integra was 76.2%; the median take rate was 98%. The mean take rate of epidermal autograft placed over Integra was 87.7%; the median take rate was 95%.

Hicks et al (2019) conducted a systematic review of Integra dermal regeneration template for the treatment of acute full thickness burns and burn reconstruction.(62) A total of 72 studies with 1084 patients (4 RCTs, 4 comparative studies, 5 cohort studies, 2 case control studies, 24 case series, and 33 case reports) were included in the review. The majority of patients (74%) were treated with Integra for acute burns, and the remainder (26%) for burn reconstruction. The take of the skin substitute was 86% (range 0 to 100%) for acute burn injuries and 95% (range 0 to 100%) for reconstruction. The take of the split-thickness skin graft over the template was 90% for acute burn injuries and 93% for reconstruction. There was high variability in reporting of outcomes, but studies generally supported satisfactory cosmetic results in patients who have insufficient autograft and improvement in range of motion in patients who were treated with Integra for burn reconstruction. There was an overall complication rate of 13%; primarily due to infection, graft loss, hematoma formation, and contracture.

An infection rate of 18% was noted in a systematic review of complication rates in 10 studies that used Integra dermal regeneration template for burns.(60)

Omega3 Wound

Luze et al (2022) conducted a systematic review of the use of acellular fish skin grafts in burn wound management.(64) The reviewers identified 5 studies of Omega3 Wound but no RCTs. The identified studies were preclinical (animal), case series, retrospective observational, and 1 small (N = 21) cohort study. The review authors concluded that while the approach is promising, large-cohort studies are needed.

ReCell Autologous Cell Harvesting Device

Two RCTs have evaluated Recell for deep dermal burns (Table 23).(65,66)

In both studies, 2 similar areas with a burn injury in the same individual were randomized to the control or treatment intervention (i.e., all participants received both treatments). The studies differed in their populations, interventions, and outcome measures. In the earlier study, participants all had deep partial thickness burns, while in the 2019 study the population included individuals with mixed-depth, full thickness burns. Holmes 2018 was a head-to-head comparison of ReCell alone versus skin grafting alone, and Holmes et al (2019) compared ReCell in combination with skin grafting. In the earlier study, the primary effectiveness endpoints were the incidence of wound closure at 4 weeks and the incidence of complete donor site healing at 1 week. In the 2019 trial, the co-primary effectiveness endpoints were non-inferiority of the incidence of RECELL-treated site closure by week 8 when compared to the control, and the superiority of the 37% relative reduction in donor skin for the ReCell treatment when compared with the control.

Study results are detailed in Table 24 and limitations in Tables 25 and 26. Although the ReCell device was comparable to standard care on outcomes such as complete wound closure; confidence in the strength of the overall body of evidence is limited by individual study limitations and heterogeneity of populations, interventions, and outcome measures across studies. Additional RCT evidence in the intended use population is needed.

Table 23. Randomized Controlled Trials of ReCell for Thermal Burns- Characteristics

Study; Trial	Countries	Sites	Dates	Participants	Interventions	
					Active	Comparator
Holmes et al (2018) NCT01138917	US	9	2010-2015	Individuals ages 18 to 65 years, with acute, deep partial-thickness thermal burns from 1% to 20% TBSA that required autografting for definitive closure.	ReCell device N = 101	Meshed STSG Treatment N = 101
Holmes et al (2019) NCT02380612	US	6	2015-2017	Individuals ages 5 years or older, with acute thermal burn involving 5% to 50% of TBSA that underwent autografting for definitive closure	ReCell device treatment applied over STSG N = 30	Meshed STSG Treatment Alone N = 30

STSG:: Split-thickness skin grafts; TBSA: total body surface area.

Table 24. Randomized Controlled Trials of ReCell for Thermal Burns- Results

Study	Wound Closure (95% re-epithelialization) at 4 weeks	Wound Closure (95% re-epithelialization) at 8 weeks	Complete donor site healing at 1 week (100% re-epithelialization)	Relative Reduction in Donor Skin	Pain (VAS)	Participant Satisfaction and Scar Assessment	Adverse Events (Incidence)
Holmes et al (2018) NCT01138917							

ReCell	81/83 (97.6%)	21.8%		NSD at 16 weeks (data in figure)	NSD in subject satisfaction with appearance or in scarring at 16, 24, and 52 weeks (data in figures)	Treatment site: 35.6% Donor site: 4.0%
STSG	83/83 (100%)	10.0%				Treatment site: 21.8% Donor site: 6.9%
Between-group difference	-2.4% (95% CI: -8.4% to 2.3%)	p = .04				Treatment site: p = .0013 Donor site: 6.9% p = .25
Holmes et al (2019) NCT02380612						
ReCell plus STSG	50%	24/26 (92%)	368 (SD 150) cm ²	NSD between groups in treatment area pain from week 1 to week 12 or week 52	NSD in subject satisfaction with appearance or in scar assessment at any time point	NSD between groups in pre-specified safety events 17 individuals (57%) experienced AEs at control and ReCell sites; 27% had mild AEs, 37% moderate AEs. 1 death, attributed to underlying condition
STSG alone	48%	22/26 (85%)	264 (SD 119) cm ²			
Between-group difference		-7.7% Upper limit of the 97.5% CI 6.4% (i.e. within the pre-defined non-inferiority margin 10%)	32%; p <.001			

AE: adverse events; CI: confidence interval; NSD: no significant difference; SD: standard deviation; STSG:: Split-thickness skin grafts; VAS: visual analog scale.

Table 25. Randomized Controlled Trials of ReCell for Thermal Burns- Study Relevance Limitations

Study	Population ^a	Intervention ^b	Comparator ^c	Outcomes ^d	Duration of Follow-up ^e
Holmes et al (2018) NCT01138917					
Holmes et al (2019) NCT02380612	2. Participants had mixed depth full-thickness burns			5. Unclear if 32% reduction in donor site skin is clinically meaningful	

The study limitations stated in this table are those notable in the current review; this is not a comprehensive gaps assessment.

^a Population key: 1. Intended use population unclear; 2. Study population is unclear; 3. Study population not representative of intended use; 4. Enrolled populations do not reflect relevant diversity; 5. Other.

^b Intervention key: 1. Not clearly defined; 2. Version used unclear; 3. Delivery not similar intensity as comparator; 4. Not the intervention of interest (e.g., proposed as an adjunct but not tested as such); 5. Other.

^c Comparator key: 1. Not clearly defined; 2. Not standard or optimal; 3. Delivery not similar intensity as intervention; 4. Not delivered effectively; 5. Other.

^d Outcomes key: 1. Key health outcomes not addressed; 2. Physiologic measures, not validated surrogates; 3. Incomplete reporting of harms; 4. Not establish and validated measurements; 5. Clinically significant difference not prespecified; 6. Clinically significant difference not supported; 7. Other.

^e Follow-Up key: 1. Not sufficient duration for benefit; 2. Not sufficient duration for harms; 3. Other.

Table 26. Randomized Controlled Trials of ReCell for Thermal Burns- Study Design and Conduct Limitations

Study	Allocation ^a	Blinding ^b	Selective Reporting ^c	Data Completeness ^d	Power ^e	Statistical ^f
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Holmes et al (2018)	83/101 participants evaluated in modified per protocol analysis	noninferiority margin based on 90 subjects
NCT01138917 Holmes et al (2019)	26/30 participants evaluated in per protocol analysis	3. confidence intervals not reported
NCT02380612		

The study limitations stated in this table are those notable in the current review; this is not a comprehensive gaps assessment.

^a Allocation key: 1. Participants not randomly allocated; 2. Allocation not concealed; 3. Allocation concealment unclear; 4.

Inadequate control for selection bias; 5. Other.

^b Blinding key: 1. Participants or study staff not blinded; 2. Outcome assessors not blinded; 3. Outcome assessed by treating physician; 4. Other.

^c Selective Reporting key: 1. Not registered; 2. Evidence of selective reporting; 3. Evidence of selective publication; 4. Other.

^d Data Completeness key: 1. High loss to follow-up or missing data; 2. Inadequate handling of missing data; 3. High number of crossovers; 4. Inadequate handling of crossovers; 5. Inappropriate exclusions; 6. Not intent to treat analysis (per protocol for noninferiority trials); 7. Other.

^e Power key: 1. Power calculations not reported; 2. Power not calculated for primary outcome; 3. Power not based on clinically important difference; 4. Other.

^f Statistical key: 1. Analysis is not appropriate for outcome type: (a) continuous; (b) binary; (c) time to event; 2. Analysis is not appropriate for multiple observations per patient; 3. Confidence intervals and/or p values not reported; 4. Comparative treatment effects not calculated; 5. Other.

Section Summary: Deep Dermal Burns

Epicel is FDA-approved under an HDE for the treatment of deep dermal or full-thickness burns comprising a TBSA of 30% or more, with patient survival of 90%. Integra Dermal Regeneration Template has been compared with autograft in a within-subject study and with autograft-allograft in a small RCT with 10 patients per group. Outcomes are at least as good as with autograft or allograft, with a reduction in scarring and without risks associated with cadaver skin. This product has also been studied in a large series with over 222 burn patients, showing a take rate of 76% and with a take rate of epidermal autograft placed over Integra of 87.7%.

The ReCell device has been evaluated in 2 RCTs. One RCT evaluated ReCell as an adjunct to meshed autologous skin grafting and the other compared ReCell head-to-head with skin grafting. Although the ReCell device was comparable to standard care on outcomes such as complete wound closure, confidence in the strength of the overall body of evidence is limited by individual study limitations and heterogeneity of populations, interventions, and outcome measures across studies. Additional RCT evidence in the intended use population is needed.

OTHER INDICATIONS

DYSTROPHIC EPIDERMOLYSIS BULLOSA

OrCel was approved under a humanitarian device exemption (HDE) for use in patients with dystrophic epidermolysis bullosa undergoing hand reconstruction surgery, to close and heal wounds created by the surgery, including those at donor sites. HDE status has been withdrawn for Dermagraft for this indication.

Fivenson et al (2003) reported the off-label use of Apligraf in 5 patients with recessive dystrophic epidermolysis bullosa who underwent syndactyly release.(67)

Section Summary: Dystrophic Epidermolysis Bullosa

Dystrophic epidermolysis bullosa is a rare disorder. Because this is a rare disorder, it is unlikely that RCTs will be conducted to evaluate whether OrCel improves health outcomes for this condition.

Punch Biopsy Wounds

Baldursson et al (2015) reported a double-blinded RCT with 81 patients (162 punch biopsy wounds) that compared Kerecis Omega3 Wound (derived from fish skin) with Oasis SIS ECM (porcine small intestinal submucosa extracellular matrix).(68) The primary outcome (the percentage of wounds healed at 28 days) was similar for the fish skin ADM (95%) and the porcine SIS ECM (96.3%). The rate of healing was faster with Kerecis Omega3 ($p=0.041$). At 21 days, 72.5% of the fish skin ADM group had healed compared with 56% of the porcine SIS ECM group. Interpretation of this study is limited because it did not include an accepted control condition for this indication.

Split-Thickness Donor Sites

There is limited evidence to support the efficacy of OrCel compared with SOC for the treatment of split-thickness donor sites in burn patients. In 2003, Still et al examined the safety and efficacy of bilayered OrCel to facilitate wound closure of split-thickness donor sites in 82 severely burned patients.(69) Each patient had two designated donor sites that were randomized to a single treatment of OrCel or standard dressing (Biobrane-L). The healing time for OrCel sites was significantly shorter than for sites treated with a standard dressing, enabling earlier re-cropping. OrCel sites also exhibited a nonsignificant trend for reduced scarring. Additional studies are needed to evaluate the effect of this product on health outcomes.

Pressure Ulcers

Brown-Etris et al (2019) reported an RCT of 130 patients with stage III or stage IV pressure ulcers who were treated with Oasis Wound Matrix (extracellular collagen matrix derived from porcine small intestinal submucosa) plus SOC or SOC alone.(70) At 12 weeks, the proportion of wounds healed in the collagen matrix group was 40% compared to 29% in the SOC group. This was not statistically significant ($p=0.111$). There was a statistical difference in the proportion of patients who achieved 90% wound healing (55% vs. 38% $p=0.037$), but complete wound healing is the preferred and most reliable measure. It is possible that longer follow-up may have identified a significant improvement in the percent of wounds healed. The study did include six-month follow-up, but there was high loss to follow-up and an insufficient number of patients at this time point for statistical comparison.

In the propensity matched study by Gurtner et al (2020) described above, Theraskin improved the healing rate of pressure ulcers by 20% (66.7% vs 46.8%).(71)

Peripheral Nerve Injuries

The Cochrane Collaboration published a meta-analysis of bioengineered nerve conduits and wraps for repairs of peripheral nerves of the upper extremity.(72) The authors included only RCTs or quasi-RCT experimental studies and found 5 which included the desired interventions and had follow-up periods of at least 12 months. A total of 213 participants were included in the studies, which compared nerve reconstruction with artificial wraps or conduits to standard repair either with direct end-to-end epineural repair or with autologous nerve grafting. Sensory recovery assessed with the British Medical Research Council (BMRC) grading scale was higher in the wrap or conduit group than in standard repair with very low certainty of evidence on Grading of Recommendations, Assessment, Development, and Evaluations (GRADE) at 12 months (mean difference [MD], .03; range, -0.43 to 0.49) and 24 months follow-up (MD, .01; 95% CI, -0.06 to 0.08). Rosen model instrument (RMI) comparisons between conduit or wrap versus standard repair revealed no between-group differences through 24 months (MD, -0.17; 95% CI, -0.38 to 0.05; $p=.13$) and was determined to have low certainty of evidence; findings

at 5 years follow-up in a single study found a greater improvement in the conduit or wrap group, but the estimate also had low certainty of evidence (MD, 0.23; 95% CI, 0.07 to 0.38). The rate of adverse event occurrence may be greater in patients treated with nerve wraps or conduits than with standard techniques, but the evidence had a GRADE rating reflected a very low certainty of evidence (risk ratio [RR], 7.15; 95% CI, 1.74 to 29.42). The authors also sought BMRC muscle strength scores, which were not reported in the included studies. The authors concluded that based on the currently available high-quality evidence, the use of currently available nerve repair devices is not supported over the standard of care due to heterogeneity in included participants, the pattern of injury, timing of repair, timing of outcome assessment, and choice of outcome measurement scales. A limitation of this systematic review is that they did not explicitly separate studies by the use of nerve conduits versus wraps for further analysis.

Miscellaneous

In addition to indications previously reviewed, off-label uses of bioengineered skin substitutes have included pressure ulcers, inflammatory ulcers (e.g., pyoderma gangrenosum, vasculitis), scleroderma digital ulcers, post-keloid removal wounds, genetic conditions, and variety of other conditions.(73) Products that have been FDA-approved or -cleared for one indication (e.g., lower-extremity ulcers) have also been used off-label in place of other FDA-approved or -cleared products (e.g., for burns).(74) No controlled trials were identified for these indications.

Supplemental Information

PRACTICE GUIDELINES AND POSITION STATEMENTS

National Institute for Health and Care Excellence

In 2023, the National Institute for Health and Care Excellence updated its guidance on the prevention and management of diabetic foot problems.(75) The Institute recommended that clinicians “consider dermal or skin substitutes as an adjunct to standard care when treating diabetic foot ulcers, only when healing has not progressed and on the advice of the multidisciplinary foot care service.”

In 2019, NICE published guidance on the ReCell system for treating skin loss, scarring, and depigmentation after burn injury.(76) The guidance recommended that additional research was needed to address the uncertainties regarding the potential benefits of ReCell.

U.S. PREVENTIVE SERVICES TASK FORCE RECOMMENDATIONS

Not applicable.

ONGOING AND UNPUBLISHED CLINICAL TRIALS

Some currently unpublished trials that might influence this review are listed in Table 6.

Table 27. Summary of Key Trials

NCT No.	Trial Name	Planned Enrollment	Completion Date
Ongoing			
NCT06616844 ^a	Evaluating the Efficacy of Porcine Placental Extracellular Matrix Augmented Wound Care Against Standard Wound Care for the Management of Diabetic Foot Ulcers: a Multi-center,	194	Jul 2026

	Prospective, Observer-blinded, Randomized Controlled Clinical Trial.		
NCT06449638 ^a	A Multicenter, Prospective, Randomized Controlled Modified Platform Trial Assessing the Efficacy of Multiple Human Placental-Based Skin Substitutes and Standard of Care Versus SOC Alone in the Treatment of Hard-to-Heal Diabetic Foot Ulcers	272	Aug 2026
NCT06831760	A Randomized, Controlled Clinical Trial Evaluating the Efficacy of Type-I Collagen-based Skin Substitute vs. Dehydrated Human Amnion/Chorion Membrane in the Treatment of Venous Leg Ulcers	50	Jun 2026
NCT06745557 ^a	A Multicentre, Intra-patient Randomised Controlled Phase III Study to Confirm the Efficacy and Safety of DenovoSkin™, a Bilayer Engineered Collagen-based Skin Graft Composed of Autologous Fibroblasts and Keratinocytes, for the Treatment of Patients with Deep Partial and Full-thickness Burns	70	Jun 2028
NCT06557122 ^a	A Randomized Controlled Clinical Trial Evaluating the Efficacy of a Unique Advanced Bioengineered Skin Substitute With Standard of Care Versus an Active Comparator With Standard of Care in the Treatment of Non-Healing Diabetic Foot Ulcers	24	Oct 2024
NCT05291169	A Randomized, Multicenter, Open Label Study Comparing Omeza Combination Therapy with Standard of Care to Standard of Care alone for Chronic Venous Leg Ulcers over the course of 4 weeks	54 (actual)	Mar 2024
NCT05084183	An Adaptive, Randomized, Controlled Trial Evaluating the Effectiveness of PermeaDerm® (PD) as Compared to Mepilex Ag® Used as Standard of Care in the Treatment of Adult and Pediatric Partial Thickness Burns	68	Nov 2023
NCT05439746	Clinical Trial to Assess the Efficacy of Microlyte Matrix on the Healing of Surgically Created Partial Thickness Donor Site Wounds on Patients Requiring Split-thickness Skin Grafting	53	Jan 2024
NCT05506215	A Prospective, Multicenter, Open Label, Randomized, Controlled Clinical Study Evaluating the Effect of NovoSorb® SynPath™ Dermal Matrix Compared to Standard of Care (SOC) In the Treatment of Nonresponsive, Chronic Diabetic Foot Ulcers.	25 (terminated)	Feb 2024
NCT05372809	Closure Obtained With Vascularized Epithelial Regeneration for DFUs With SkinTE®	42 (terminated)	Feb 2024
NCT02587403 ^a	A Randomized, Prospective Study Comparing Fortiva™ Porcine Dermis vs. Stratattice™ Reconstructive Tissue Matrix in Patients Undergoing Complex Open Primary Ventral Hernia Repair	120	Feb 2024
NCT04927702	Assessment of Wound Closure Comparing Synthetic Hybrid-Scale Fiber Matrix (Restrata®) With Standard of Care in Treating Diabetic Foot Ulcers (DFU) and With Living Cellular Skin Substitute (Apligraf®) in Treating Venous Leg Ulcers (VLU)	47 (terminated)	Aug 2024
NCT06035536	A Multi-Center, Randomized Controlled Clinical Investigation Evaluating Wound Closure With Symphony™ Versus Standard of Care in the Treatment of Non-Healing Diabetic Foot Ulcers	120	Dec 2024
NCT05517902	A Phase 3 Multicenter, Single-Arm, Open-Label Study Evaluating the Safety, Tolerability and Efficacy of StrataGraft® Construct in Pediatric Subjects With Deep Partial Thickness (DPT) Thermal Burns	1 (actual)	Jun 2025
NCT04090424	A Pivotal Study to Assess the Safety and Effectiveness of NovoSorb® Biodegradable Temporizing Matrix (BTM) in the Treatment of Severe Burn Skin Injuries	150	Dec 2025
NCT03394612	A Phase II, Prospective, Intra-patient Randomised Controlled, Multicentre Study to Evaluate the Safety and Efficacy of an Autologous Bio-engineered Dermo-epidermal Skin Substitute	20	Dec 2026

	(EHSG-KF; denovoSkin) for the Treatment of Full-Thickness Defects in Adults and Children in Comparison to Autologous Split-thickness Skin Grafts (STSG)		
Unpublished			
NCT06470087	A Randomized Controlled Clinical Trial Comparing High Purity Type-I Collagen-based Skin Substitute to Dehydrated Human Amnion/Chorion Membrane in the Treatment of Diabetic Foot Ulcers	28	Sept 2024
NCT02322554	The Registry of Cellular and Tissue Based Therapies for Chronic Wounds and Ulcers	50,000	Jan 2020
NCT03935386 ^a	A Prospective Randomized Clinical Trial Comparing Multi-layer Bandage Compression Therapy With and Without a Biologically Active Human Skin Allograft (Theraskin) for the Treatment of Chronic Venous Leg Ulcers	100	Dec 2020
NCT03589586 ^a	An Open-Label Trial to Assess the Clinical Effectiveness of DermACELL AWM in Subjects With Chronic Venous Leg Ulcers	100	Mar 2021
NCT03881254	A Multi-center, Randomized Controlled Clinical Trial Evaluating the Effects of SkinTE™ in the Treatment of Wagner One Diabetic Foot Ulcers	100	Jul 2021
NCT04198441	A Randomized, Multicenter, Open Label Study Comparing the Omeza® Products Bundle to Standard of Care for Chronic Venous Leg Ulcers and Chronic Diabetic Foot Ulcers	78	Dec 2021
NCT04257370 ^a	An Open Label, Randomized Controlled Study to Compare Healing of Severe Diabetic Foot Ulcers and Forefoot Amputations in Diabetics With and Without Moderate Peripheral Arterial Disease Treated With Kerecis Omega3 Wound and SOC vs. SOC Alone	260 (actual)	Nov 2022
NCT04537520 ^a	Interventional Multi-Center Post Market Randomized Controlled Open-Label Clinical Trial Comparing Kerecis Omega3 Wound Versus SOC in Hard to Heal Diabetic Foot Wounds	180	Dec 2022
NCT04918784	Assessment of Wound Closure Comparing Synthetic Hybrid-Scale Fiber Matrix (Restrata®, Acera Surgical, Inc.) With Standard of Care in Treating Diabetic Foot Ulcer	46	Dec 2022
NCT05883098	Effectiveness of Supra SDRM® vs. Fibracol Plus Collagen in the Treatment of Diabetic Foot Ulcers: a Pilot Randomized Controlled Trial	30	Jun 2023

NCT: national clinical trial.

^a Denotes industry-sponsored or cosponsored trial.

Regulatory Status

The U.S. Food and Drug Administration (FDA) does not refer to any single product or class of products as “skin substitutes”. Products in this review cover products that do not require FDA approval or clearance as well as a number of products cleared through the 510(k) pathway with a variety of FDA product codes. A large number of artificial skin products are commercially available or in development. Commercial availability is not a reflection of a product's regulatory status. The following section summarizes a subset of commercially available skin and soft-tissue skin substitutes. This is not a complete list of all commercially available products. Information on additional products is available in a 2020 Technical Brief on skin substitutes for treating chronic wounds that was commissioned by the Agency for Healthcare Research and Quality.(1)

Acellular Dermal Matrix Products

Allograft ADM products derived from donated human skin tissue are supplied by tissue banks compliant with standards of the American Association of Tissue Banks and U.S. Food and Drug Administration (FDA) guidelines. The processing removes the cellular components (i.e., epidermis, all viable dermal cells) that can lead to rejection and infection. ADM products from human skin tissue are regarded as minimally processed and not significantly changed in structure from the natural material; FDA classifies ADM products as banked human tissue and therefore, ADMs do not require FDA approval for homologous use.

In 2017, FDA published clarification of what is considered minimal manipulation and homologous use for human cells, tissues, and cellular and tissue-based products (HCT/Ps).(2)

HCT/Ps are defined as human cells or tissues that are intended for implantation, transplantation, infusion, or transfer into a human recipient. If an HCT/P does not meet the criteria below and does not qualify for any of the stated exceptions, the HCT/P will be regulated as a drug, device, and/or biological product and applicable regulations and premarket review will be required.

An HCT/P is regulated solely under section 361 of the PHS Act and 21 CFR Part 1271 if it meets all of the following criteria:

1. The HCT/P is minimally manipulated;
2. The HCT/P is intended for homologous use only, as reflected by the labeling, advertising, or other indications of the manufacturer's objective intent;
3. The manufacture of the HCT/P does not involve the combination of the cells or tissues with another article, except for water, crystalloids, or a sterilizing, preserving, or storage agent, provided that the addition of water, crystalloids, or the sterilizing, preserving, or storage agent does not raise new clinical safety concerns with respect to the HCT/P; and
4. Either: i) The HCT/P does not have a systemic effect and is not dependent upon the metabolic activity of living cells for its primary function; or ii) The HCT/P has a systemic effect or is dependent upon the metabolic activity of living cells for its primary function, and:
 - a) Is for autologous use; b) Is for allogeneic use in a first-degree or second-degree blood relative; or c) Is for reproductive use."

- AlloDerm® (LifeCell Corp.) is an ADM (allograft) tissue-replacement product created from native human skin and processed so that the basement membrane and cellular matrix remain intact. Originally, AlloDerm® required refrigeration and rehydration before use. It is currently available in a ready-to-use product stored at room temperature. An injectable micronized form of AlloDerm® (Cymetra) is available.
- Cortiva® (previously marketed as AlloMax™ Surgical Graft and before that NeoForm™) is an acellular non-cross-linked human dermis allograft.
- AlloPatch® (Musculoskeletal Transplant Foundation) is an acellular human dermis allograft derived from the reticular layer of the dermis and marketed for wound care. This product is also marketed as FlexHD® for postmastectomy breast reconstruction.
- FlexHD® and the newer formulation FlexHD® Pliable™ (Musculoskeletal Transplant Foundation) are acellular hydrated reticular dermis allograft derived from donated human skin.
- DermACELL™ (LifeNet Health) is an allogeneic ADM processed with proprietary technologies MATRACELL® and PRESERVON®.
- DermaMatrix™ (Synthes) is a freeze-dried ADM derived from donated human skin tissue. DermaMatrix Acellular Dermis is processed by the Musculoskeletal Transplant Foundation.

- DermaPure™ (Tissue Regenix Wound Care) is a single-layer decellularized human dermal allograft for the treatment of acute and chronic wounds.
- Graftjacket® Regenerative Tissue Matrix (also called Graftjacket Skin Substitute; KCI) is an acellular regenerative tissue matrix that has been processed from human skin supplied from U.S. tissue banks. The allograft is minimally processed to remove the epidermal and dermal cells while preserving dermal structure. Graftjacket Xpress® is an injectable product.
- mVASC® (MicroVascular Tissues, Inc.) is a microvascular tissue structural allograft made of small blood vessels and extracellular matrix, inherent non-viable cells, and associated biological signaling factors harvested from subcutaneous tissue of cadaveric human donors.
- TheraSkin® (LifeNet Health) is a cryopreserved split-thickness human skin allograft composed of living fibroblasts and keratinocytes and an extracellular matrix in epidermal and dermal layers. TheraSkin® is derived from human skin allograft supplied by tissue banks compliant with the American Association of Tissue Banks and FDA guidelines. It is considered a minimally processed human cell, tissue, and cellular- and tissue-based product by the FDA.

Although frequently used by surgeons for breast reconstruction, FDA does not consider this homologous use and has not cleared or approved any surgical mesh device (synthetic, animal collagen-derived, or human collagen-derived) for use in breast surgery. The indication of surgical mesh for general use in “Plastic and reconstructive surgery” was cleared by the FDA before surgical mesh was described for breast reconstruction in 2005. FDA states that the specific use of surgical mesh in breast procedures represents a new intended use and that a substantial equivalence evaluation via 510(k) review is not appropriate and a pre-market approval evaluation is required.(3)

In March 2019, the FDA held an Advisory Committee meeting on breast implants, at which time the panel noted that while there is data about ADM for breast reconstruction, the FDA has not yet determined the safety and effectiveness of ADM use for breast reconstruction. The panel recommended that patients are informed and also recommended studies to assess the benefit and risk of ADM use in breast reconstruction.(3)

In March 2021, FDA issued a Safety Communication to inform patients, caregivers, and health care providers that certain ADM products used in implant-based breast reconstruction may have a higher chance for complications or problems. An FDA analysis of patient-level data from real-world use of ADMs for implant-based breast reconstruction suggested that 2 ADMs—FlexHD and Allomax—may have a higher risk profile than others.(4)

In October 2021, an FDA advisory panel on general and plastic surgery voted against recommending FDA approval of the SurgiMend mesh for the specific indication of breast reconstruction. The advisory panel concluded that the benefits of using the device did not outweigh the risks.(4)

FDA product codes: FTM, OXF.

Xenogeneic Products

Apis® is fully absorbable, biodegradable and manufactured using a porcine collagen derivative, Manuka honey and hydroxyapatite. It was cleared for marketing (2019) by the FDA 510(k) process for the management of full and partial thickness wounds, pressure ulcers

(stages I-IV), venous stasis ulcers, diabetic ulcers, abrasion, surface wounds, traumatic wounds (healing by secondary intention), donor site wounds, and surgical wounds.

Atlas Wound Matrix is a sterile, decellularized fenestrated or non-fenestrated processed porcine collagen dermal material. It was cleared for marketing (2009) by the FDA 510(k) process for the management of partial and full thickness wounds, pressure ulcers, venous ulcers, diabetic ulcers, chronic vascular ulcers, tunneled/undermined wounds, surgical wounds (donor sites/grafts, post-Moh's surgery, post-laser surgery, podiatric, wound dehiscence), trauma wounds (abrasions, lacerations, second-degree burns, and skin tears), and draining wounds.

The bio-ConneKt Wound Matrix is a sterile, conformable and porous wound dressing made of reconstituted collagen derived from equine tendon. It is chemically crosslinked to provide resistance to enzymatic degradation. The dressing is provided sterile for single use only. For the local management of moderately to heavily exuding wounds, including: partial and full thickness wounds, draining wounds, tunneling wounds, pressure sores/ulcers, venous ulcers, chronic vascular ulcers, diabetic ulcers, trauma wounds (e.g., abrasions, lacerations, partial thickness burns, skin tears), surgical wounds (e.g., donor sites/grafts, post-laser surgery, post-Mohs' surgery, podiatric wounds, and dehisced surgical incisions).

Cytal™ (previously called MatriStem®) Wound Matrix, Multilayer Wound Matrix, Pelvic Floor Matrix, MicroMatrix, and Burn Matrix (all manufactured by ACell) are composed of porcine-derived urinary bladder matrix. Cytal® Wound Matrix is intended for the management of wounds including: partial and full-thickness wounds, pressure ulcers, venous ulcers, diabetic ulcers, chronic vascular ulcers, tunnel/undermined wounds, surgical wounds (donor sites/grafts, post-Mohs surgery, post-laser surgery, podiatric, wound dehiscence), trauma wounds (abrasions, lacerations, second-degree burns, and skin tears), and draining wounds. The device is intended for one-time use.

Endoform® Reconstructive Template – Non-Absorbable ([Aroa Biosurgery, Limited] aka: OviTex IHR Reinforced Tissue Matrix; OviTex LPR Reinforced Tissue Matrix; OviTex Reinforced Tissue Matrix with Permanent Polymer [OviTex]) is a surgical mesh manufactured by layering sheets of ovine forestomach matrix (OFM) to create 1- through 10- ply embroidered devices for soft tissue reconstruction. The device design includes thicknesses from 1- through 10-ply to give a range of strengths as required for a particular implant procedure. The construction of Endoform™ Reconstructive Template - Non-Absorbable devices includes lyophilization of single sheets of OFM followed by embroidery with polypropylene. Devices are terminally sterilized by ethylene oxide (EO) sterilization. Endoform® Reconstructive Template – Non-Absorbable was cleared for marketing (2016 [K153632]; updated 2018 [K181935]) by the FDA 510(k) process for use as a surgical mesh to reinforce and/or repair soft tissue where weakness exists. Indications for use include the repair of hernias and/or abdominal wall defects that require the use of reinforcing or bridging material to obtain the desired surgical outcome.

Endoform® Reconstructive Template (Aroa Biosurgery Ltd.; aka: OviTex Reinforced Tissue Matrix with Resorbable Polymer [OviTex]) is a surgical mesh manufactured by layering sheets of ovine forestomach matrix (OFM) to create 1- through 10- ply embroidered devices for implant applications as part of soft tissue reconstruction. The device design includes a range of thicknesses from 1- through 10- ply to give a range of strengths as required for a particular implant procedure. The construction of ERT devices includes

lyophilization of single sheets of OFM followed by embroidery with polyglycolic acid (PGA). Devices are terminally sterilized by ethylene oxide (EO) sterilization. The device received 510(K) FDA clearance (2016; K153633) for sizes up to 400cm².

EZ Derm (Brennen Medical, Inc.) is a porcine derived xenograft in which the collagen has been cross linked with an aldehyde. EZ Derm (porcine xenograft) can be used for partial thickness skin loss injuries. Use of EZ Derm for burns, donor sites and chronic vascular ulcers reduces pain and fluid loss. EZ Derm can also be used as a temporary cover, or test graft, prior to auto grafting and as a protective covering over perforated auto grafts. FDA 510(k) approval was granted in 1994 (K935189). A recall of the product was posted effective 4/30/2019.

Foundation Dermal Regeneration Scaffold (DRS) Solo comprises of a porous matrix of chitosan derived from shellfish and sodium chondroitin sulfate, a glycosaminoglycan. FDA 510(k) clearance was granted in 2023 (K231937). Indications for use include management of full thickness and partial thickness wounds; pressure ulcers; venous ulcers; ulcers caused by mixed vascular etiologies; diabetic ulcers; partial thickness burns (superficial second-degree burns); donor sites and other bleeding surface wounds; abrasions; trauma wounds (abrasions, lacerations, skin tears); dehiscent wounds; and surgical wounds (donor sites/grafts, post-Moh's surgery, post-laser surgery, podiatric, wound dehiscence).

Geistlich Derma-Gide is derived from porcine tissue (mostly collagen Type I) and is processed using proprietary technologies to remove bacteria and inactive viruses. It was cleared for marketing by the FDA 510(k) process (2018) for the management of partial and full thickness wounds, pressure ulcers, venous ulcers, diabetic ulcers, chronic vascular ulcers, surgical wounds (donor sites/grafts, post Moh's surgery, post laser surgery, podiatric, wound dehiscence), and trauma skin wounds (abrasions, laceration, second degree burns, skin tears).

Helicoll (Encol) is an acellular collagen matrix derived from bovine dermis. In 2004, it was cleared for marketing by the FDA through the 510(k) process for topical wound management that includes partial and full-thickness wounds, pressure ulcers, venous ulcers, chronic vascular ulcers, diabetic ulcers, trauma wounds (e.g., abrasions, lacerations, second-degree burns, skin tears), and surgical wounds including donor sites/grafts.

Innovaburn™ (Triad Life Sciences, Inc.)™ is a decellularized extracellular matrix (ECM) topical wound covering derived from porcine placental tissue. Triad processes the tissue into the ECM topical wound covering. InnovaBurn™ is composed of collagen, elastin, laminin, fibronectin, hyaluronic acid and sulfated glycosaminoglycans. The wound dressing is provided in sheets that are approximately 40-100 microns thick in sizes greater than 5 x 5cm (25cm²) up to 20 x 20cm (400cm²). Innovaburn was cleared for marketing (K 213716; 2022) by the FDA 510(k) process for the management of wounds including: partial- and full-thickness wounds, pressure ulcers, venous ulcers, diabetic ulcers, chronic vascular ulcers, tunneled/undermined wounds, surgical wounds (donor sites/grafts, post-Mohs surgery, post-laser surgery, podiatric, wound dehiscence), trauma wounds (abrasions, lacerations, and skin tears), partial-thickness second degree burns, and draining wounds.

InnovaMatrix™ (also known as InnovaMatrix AC) and InnovaMatrix™ FS are decellularized extracellular matrix topical wound coverings derived from porcine placental tissue. The only modification made to InnovaMatrix FS since the InnovaMatrix clearance is the addition of fenestrations. Both devices have been cleared for marketing (InnovaMatrix AC – 2020;

InnovaMatrix FS - 2021) by the FDA 510(k) process for the management of wounds including: partial- and full-thickness wounds, pressure ulcers, venous ulcers, diabetic ulcers, chronic vascular ulcers, tunneled/undermined wounds, surgical wounds (donor sites/grafts, post-Mohs surgery, post-laser surgery, podiatric, wound dehiscence), trauma wounds (abrasions, lacerations, second degree burns and skin tears) and draining wounds.

InnovaMatrix® PD is a powder manufactured from the decellularized extracellular matrix (ECM) derived from porcine placental tissue. InnovaMatrix® PD was cleared for marketing (K211902; 2022) by the FDA 510(k) process for the management of wounds including: partial- and full-thickness wounds, pressure ulcers, venous ulcers, diabetic ulcers, chronic vascular ulcers, tunneled/undermined wounds, surgical wounds (donor sites/grafts, post-Mohs surgery, post-laser surgery, podiatric, wound dehiscence), trauma wounds (abrasions, lacerations, and skin tears), draining wounds, and partial-thickness burns.

Note: No FDA approval noted for InnovaMatrix XL

Integra® Matrix Wound Dressing (previously known as Avagen) is an advanced wound dressing comprised of a porous matrix of cross-linked bovine tendon collagen and glycosaminoglycan. The biodegradable matrix provides a scaffold for cellular invasion and capillary growth. It was cleared for marketing by the FDA through the 510(k) process in 2002. The wound dressings are indicated in the management of partial and full-thickness wounds, pressure ulcers, venous ulcers, diabetic ulcers, chronic vascular ulcers, tunneled undermined wounds, surgical wounds (donor sited grafts, post-Moh's surgery, post-laser surgery, podiatric, wound dehiscence), trauma wounds (abrasions, lacerations, second-degree bums, and skin tears) and draining wounds. The device is intended for one-time use.

Keramatrix® (Keraplast Research) is an open-cell foam comprised of freeze-dried keratin that is derived from acellular animal protein. In 2009, it was cleared for marketing by the FDA through the 510(k) process under the name of Keratec. The wound dressings are indicated in the management of the following types of dry, light, and moderately exudating partial and full-thickness wounds: pressure (stage I-IV) and venous stasis ulcers, ulcers caused by mixed vascular etiologies, diabetic ulcers, donor sites, and grafts.

Kerecis™ Omega3 Wound (Kerecis; previously known as MeriGen) is an ADM derived from fish skin. It has a high content of omega 3 fatty acids and is intended for use in partial and full-thickness wounds, pressure ulcers, venous ulcers, chronic vascular ulcers, diabetic ulcers, trauma wounds (abrasions, lacerations, second-degree burns, skin tears), surgical wounds (donor sites/grafts, post-Mohs surgery, post-laser surgery, podiatric, wound dehiscence), and draining wounds.

Kerecis Limited MariGen Wound Extra is processed fish dermal matrix composed of fish collagen. MariGen Wound Extra is indicated for the management of wounds, including: Partial and full-thickness wounds, Pressure ulcers, Venous ulcers, Chronic vascular ulcers, Diabetic ulcers, Trauma wounds (second degree burn, abrasions, lacerations, skin tears), Surgical wounds (donor sites/grafts, post-Mohs surgery, post laser surgery, podiatric, wound dehiscence), and Draining wounds.

Note: Kerecis has multiple U.S. wound, surgical and burn products. Not all are FDA approved (i.e., Wounds: Marigen Standard, Marigen Micro, Marigen Expanse, Marigen Shield; Burns:

Graftguide Standard, Graftguide Micro, Graftguide Mano; Surgical: Surgiclose Standard, Surgiclose Micro, Surgibind Standard)

MatriDerm is a single-use three dimensional acellular dermal matrix composed of bovine collagen fibers and bovine elastin. It was cleared for marketing (2020) by the FDA 510(k) process for the management of wounds including full thickness and partial thickness wounds, chronic wounds (e.g. pressure ulcers, venous ulcers, diabetic ulcers, chronic ulcers), surgical wounds (donor sites/grafts, post-Moh's surgery, post-laser surgery, podiatric, wound dehiscence), partial thickness burns, trauma wounds (abrasions, lacerations and skin tears), draining wounds.

Mediskin (Brennen Medical, Inc) is a porcine derived xenograft which was cleared for marketing (1995) by the FDA 510(k) process for the management of wounds including: full thickness and partial thickness wounds, chronic wounds (e.g. pressure ulcers, venous ulcers, diabetic ulcers, chronic ulcers), surgical wounds (donor sites/grafts, post-Moh's surgery, post-laser surgery, podiatric, wound dehiscence), partial thickness burns, trauma wounds (abrasions, lacerations and skin tears), draining wounds.

MicroMatrix® is composed of porcine-derived extracellular matrix scaffolds, specifically known as urinary bladder matrix. It was cleared for marketing (2016) by the FDA 510(k) process for the management of topical wounds including: partial and full thickness wounds, pressure ulcers, venous ulcers, diabetic ulcers, chronic vascular ulcers, tunnel/undermined wounds, surgical wounds (donor sites/grafts, post-Mohs surgery, post-laser surgery, podiatric, wound dehiscence), trauma wounds (abrasions, lacerations, second-degree burns, and skin tears), and draining wounds. The device is intended for one-time use.

MicroMatrix Flex® is a flexible syringe tip that provides for delivery of porcine urinary bladder matrix technology. It was cleared for marketing (2023) by the FDA 510(k) process for the management of wounds including: partial and full-thickness wounds, pressure ulcers, venous ulcers, diabetic ulcers, chronic vascular ulcers, tunneled/undermined wounds, surgical wounds (donor sites/grafts, post-Mohs surgery, post-laser surgery, podiatric, wound dehiscence), trauma wounds (abrasions, lacerations, partial thickness burns, skin tears), and draining wounds. The device is intended for one-time use.

Miro3D Fibers Wound Matrix (Reprise Biomedical, Inc.) is an acellular wound dressing that is derived from porcine liver tissue. FDA 510(k) approval (K240753) was received (2024) for the management of wounds including: partial and full thickness wounds; pressure ulcers; venous ulcers; chronic vascular ulcers; diabetic ulcers; tunneled, undermined wounds; trauma wounds (abrasions, lacerations, partial thickness burns, and skin tears); draining wounds; and surgical wounds (donor sites/grafts, post-mohs' surgery, post-laser surgery, podiatric, wound dehiscence).

Miro3D Wound Matrix (Reprise Biomedical) is derived from porcine liver tissue. In 2022, FDA 510(k) approval (K221520) was granted for use in partial and full thickness wounds; pressure ulcers; venous ulcers; chronic vascular ulcers; diabetic ulcers; tunneled, undermined wounds; trauma wounds (abrasions, lacerations, second-degree burns, and skin tears); draining wounds; and surgical wounds (donor sites/grafts, post-Mohs' surgery, post-laser surgery, podiatric, wound dehiscence). Product code: KGN.

MiroDry Wound Matrix (Reprise Biomedical) is an acellular wound dressing that is derived from porcine liver tissue. FDA 510(k) approval was received (2024) for the use in partial and full thickness wounds; pressure ulcers; venous ulcers; chronic vascular ulcers; diabetic ulcers; tunneled, undermined wounds; trauma wounds (abrasions, lacerations, partial thickness burns, and skin tears); draining wounds; and surgical wounds (donor sites/grafts, post-Mohs' surgery, post-laser surgery, podiatric, wound dehiscence). Product code: KGN.

Miromatrix Wound Matrix is an animal-sourced, acellular wound dressing that is derived from porcine liver tissue. FDA 510(k) approval (K140510) was received (2014) for use in the following partial and full thickness wounds: pressure ulcers; venous ulcers; diabetic ulcers; chronic vascular ulcers; tunneled, undermined wounds; surgical wounds (donor sites/grafts, post-mohs' surgery, post-laser surgery, podiatric, wound dehiscence); trauma wounds (abrasions, lacerations, second-degree burns, and skin tears); draining wounds.

MiroTract Wound Matrix is a guidewire which is designed to deliver wound matrix to tunneling wounds. It was cleared for marketing (2023) by the FDA 510(k) process for the management of wounds including: partial and full-thickness wounds, pressure ulcers, venous ulcers, diabetic ulcers, chronic vascular ulcers, tunneled/undermined wounds, trauma wounds (abrasions, lacerations, partial-thickness burns, and skin tears), draining wounds, surgical wounds (donor sites/grafts, post-Mohs' surgery, post-laser surgery, podiatric, wound dehiscence).

Myriad Particles (Aroa Biosurgery Ltd.) derived from an extracellular matrix primarily composed of ovine collagen and is supplied as a sterile particulate. FDA clearance (K200502) via the 510(k) process was granted (2021) and is intended to cover, protect and provide a moist wound environment. Myriad™ Particles is indicated for use in the management of partial and full-thickness wounds; ;pressure ulcers; venous ulcers; diabetic ulcers; chronic vascular ulcers; tunneled/undermined wounds; surgical wounds (donor sites/grafts, post-Moh's surgery, post-laser surgery, podiatric, wound dehiscence); trauma wounds (abrasions, lacerations, partial-thickness burns, and skin tears); and draining wounds.

Note: Other Aroa Biosurgery Ltd. products which are not FDA approved include: Myriad Matrix, Myriad Morcells, Myriad Morcells Fine, and Reinforced Bioscaffolds.

NeoMatriX® is fabricated from the dermal extracellular matrix of axolotl. NeoMatriX® Wound Matrix is intended for management of wounds including: partial and full-thickness wounds, pressure ulcers, venous ulcers, diabetic ulcers, chronic vascular ulcers, tunneled/undermined wounds, surgical wounds (donor sites/grafts, Moh's surgery, post-laser surgery, podiatric, and wound dehiscence), trauma wounds (abrasions, lacerations, partial thickness burns, and skin tears), and draining wounds. The device is intended for one-time use.

Oasis™ Wound Matrix (Cook Biotech) is a collagen scaffold (extracellular matrix) derived from porcine small intestinal submucosa. In 2000, it was cleared for marketing by the FDA through the 510(k) process for the management of omeza and is approved for wounds including: partial and full-thickness wounds, pressure ulcers, venous ulcers, diabetic ulcers, chronic vascular ulcers, tunneled/undermined wounds, surgical wounds (donor sites/grafts, Moh's surgery, post-laser surgery, podiatric, and wound dehiscence), trauma wounds (abrasions, lacerations, second-degree burns, and skin tears), and draining wounds.

Note: Cook Biotech has multiple U.S. wound, surgical and burn products. Not all are FDA approved. No FDA approval was noted for the following products:

- Oasis® Burn Matrix is a natural extracellular matrix (ECM) derived from 2 layers of porcine small intestinal submucosa.
- Oasis® Ultra Tri-Layer Matrix is a natural extracellular matrix derived from 3 layers of porcine small intestinal submucosa technology.

Ologen™ Collagen Matrix is a biodegradable material composed of collagen. It is derived from porcine hide and the matrix structure has a porous configuration made of ≥90% cross-linked lyophilized porcine collagen and ≤10% glycosaminoglycans. It was cleared for marketing (2018) by the FDA 510(k) process for the management of wounds including: surgical wounds, trauma wounds, draining wounds, second degree burns, partial and full-thickness wounds, pressure ulcers, venous ulcers, vascular ulcers, diabetic ulcers, oral wounds and sores.

Omeza® Collagen Matrix is an anhydrous matrix comprised of hydrolyzed fish collagen infused with cod liver oil and other plant-derived oils and waxes. Omeza received FDA approval for one-time use in the management of wounds including partial and full thickness wounds, pressure ulcers, venous ulcers, diabetic ulcers, chronic vascular ulcers, tunneled/undermined wounds/surgical wounds (donor sites/grafts, post-Moh's surgery, post-laser surgery, podiatric, wound dehiscence), trauma wounds (abrasions, lacerations, superficial partial thickness burns, skin tears), and draining wounds. FDA product code: FRO

Ovine Tissue Matrix (TELA Bio Inc) received FDA approval (2014) for use as a surgical mesh to reinforce and/or repair soft tissue weakness. Indications include hernia repair and/or body wall defects which require the use of reinforcing or bridging material.

OviTex IHR Reinforced Tissue Matrix; OviTex LPR Reinforced Tissue Matrix; OviTex Reinforced Tissue Matrix with Permanent Polymer [OviTex; Aroa Biosurgery Limited] (aka: Endoform® Reconstructive Template – Non-Absorbable) is a surgical mesh manufactured by layering sheets of ovine forestomach matrix (OFM) to create 1- through 10- ply embroidered devices for soft tissue reconstruction. Devices up to 400 cm² are available in thicknesses from 1- through 10- ply, and larger devices up to 1000cm² are available in 4-, 6-, and 8-ply presentations. Endoform® Reconstructive Template – Non-Absorbable was cleared for marketing (2016 [K153632]; updated 2018 [K181935]) by the FDA 510(k) process for use as a surgical mesh to reinforce and/or repair soft tissue where weakness exists. Indications for use include the repair of hernias and/or abdominal wall defects that require the use of reinforcing or bridging material to obtain the desired surgical outcome.

OviTex® PRS - Long Term Resorbable (TELA Bio) is a next generation soft tissue repair platform that utilizes layers of ovine (sheep) rumen interwoven with just enough polymer suture for added strength. OviTex PRS long term resorbable received FDA approval (2023; K214070) for one-time use to reinforce soft tissue where weakness exists in individuals requiring soft tissue repair or reinforcement in plastic and reconstructive surgery.

OviTex Reinforced Tissue Matrix with Resorbable Polymer ([OviTex]; Aroa Biosurgery, Ltd; aka: Endoform® Reconstructive Template) is a surgical mesh manufactured by layering sheets of ovine forestomach matrix (OFM) to create 1- through 10- ply embroidered devices for implant applications as part of soft tissue reconstruction. The device design includes a range of thicknesses from 1- through 10- ply to give a range of strengths as required for a particular implant procedure. The construction of ERT devices includes lyophilization of single sheets of OFM followed by embroidery with polyglycolic acid (PGA).

Devices are terminally sterilized by ethylene oxide (EO) sterilization. The device received 510(K) FDA clearance (2016; K153633) for sizes up to 400cm².

PELNAC™ Bilayer Wound Matrix (aka TheraGenesis® Bilayer Wound Matrix) is a collagen-based wound matrix that consists of 2 layers which include a porcine collagen sponge layer and a silicone film layer. It was cleared for marketing (2020) by the FDA 510(k) process for the management of partial and full-thickness wounds, pressure ulcers, venous ulcers, diabetic ulcers, chronic vascular ulcers, surgical wounds (donor sites/grafts, post-Moh's surgery, post-laser surgery, podiatric, wound dehiscence), trauma wounds (abrasions, lacerations, second-degree burns, and skin tears), and draining wounds. Product code KGN.

Permacol™ (Covidien) is xenogeneic and composed of cross-linked porcine dermal collagen. Cross-linking improves the tensile strength and long-term durability but decreases pliability.

PriMatrix™ (TEI Biosciences; a subsidiary of Integra Life Sciences) is a xenogeneic ADM processed from fetal bovine dermis. It was cleared for marketing by FDA through the 510(k) process for partial- and full-thickness wounds; diabetic, pressure, and venous stasis ulcers; surgical wounds; and tunneling, draining, and traumatic wounds.

Puracol Plus Ag Collagen Wound Dressing (Medline Industries, Inc) was cleared for marketing by the FDA through the 510(k) process. It is intended to treat full thickness and partial thickness wounds, pressure ulcers, venous ulcers, ulcers caused by mixed vascular etiologies, diabetic ulcers, first and second degree burns, donor sites and other bleeding surface wounds, abrasions, trauma wounds healing by secondary intention, dehisced wounds, surgical wounds, and dehisced surgical wounds.

PuraPly (aka FortaDerm Wound Dressing [Organogenesis Inc.]) consists of a single layer fenestrated sheet of porcine intestinal collagen. FDA 510(k) approval (K011026) was granted (2001) for the management of wounds including: partial and full thickness wounds, pressure ulcers, venous ulcers, diabetic ulcers, chronic vascular ulcers, tunneled/undermined wounds, surgical wounds, (donor sites/grafts, post-Moh's surgery, post-laser surgery, wound dehiscence, trauma wounds (abrasions, lacerations second-degree burns, and skin tears, and draining wounds.

PuraPly® Antimicrobial (PuraPly AM) is a bilayered fenestrated sheet of porcine intestinal collagen coated with the broad spectrum antimicrobial agent 0.1 % Polyhexamethylene Biguanide hydrochloride. It is intended for the management of both acute and chronic wounds; and as an effective barrier to resist microbial colonization within the wound dressing and reduce microbes penetrating through the dressing. Product code: FRO

PuraPly Micronized Wound Matrix (PuraPly MZ) consists of micronized porcine collagen intended for the management of wounds. PuraPly® Micronized Wound Matrix is supplied as a dry powder of particle size of ≤ 1000µm. PuraPly MZ received FDA clearance (2022) via the 510(k) process. It is intended for single patient use in the management of wounds including partial and full-thickness wounds; pressure ulcers; venous ulcers; diabetic ulcers; chronic vascular ulcers; tunneled/undermined wounds; surgical wounds (e.g., donor sites/grafts, post-Mohs; surgery, post-laser surgery, podiatric wound, and wound dehiscence); trauma wounds (e.g., abrasions, lacerations, and skin tears); partial thickness burns; and draining wounds.

Note: There are multiple PuraPly products, not all are FDA approved (i.e. PuraPly XT)

Resolve Matrix™ (aka Meso Wound Matrix) is a resorbable porcine mesothelium derived product. It was cleared for marketing (2012) by the FDA 510(k) process for the management of topical wounds including: partial and full-thickness wounds, pressure ulcers, venous ulcers, diabetic ulcers, chronic vascular ulcers, tunneled/undermined wounds, surgical wounds (donor sites/grafts, post Moh's surgery, post-laser surgery, podiatric, wound dehiscence), trauma wounds (abrasions, lacerations, second-degree burns and skin tears) and draining wounds. In early 2022, Parametrics Medical engaged with DSM Biomedical regarding commercializing of the product which was when the product was launched under the brand name "Resolve Matrix™".

Strattice™ Reconstructive Tissue Matrix (LifeCell Corp.) is a xenogenic non-cross-linked porcine-derived ADM. There are pliable and firm versions, which are stored at room temperature and come fully hydrated. Strattice received FDA 510(k) approval (2007; K070560) as a soft tissue patch to reinforce soft tissue where weakness exists and for the surgical repair of damaged or ruptured soft tissue membranes. Indications for use include the repair of hernias and /or body wall defects which require the use of reinforcing or bridging material to obtain the desired surgical outcome.

SurgiMend is an acellular dermal tissue derived from bovine dermis. The device is available in solid, fenestrated, and perforated configurations. The device is supplied sterile in a variety of sizes, shapes, and thicknesses. FDA 510(k) approval (K162965) was granted (2017). SurgiMend is intended for implantation to reinforce soft tissue where weakness exists and for surgical repair of damaged or ruptured soft tissue membranes. SurgiMend is specifically indicated for: plastic and reconstructive surgery, muscle flap reinforcement, hernia repair including abdominal, inguinal, femoral, diaphragmatic, scrotal, umbilical, and incisional hernias.

SurgiMend® PRS (TEI Biosciences) is a xenogeneic ADM processed from fetal and neonatal bovine dermis. It was cleared for marketing (2017) by the FDA 510(k) process to reinforce soft tissue where weakness exists and for surgical repair of damaged or ruptured soft tissue membranes. SurgiMend® Meshed is specifically indicated for plastic and reconstructive surgery.

Symphony™ (Aroa BioSurgery Ltd.) is a sterile, single use wound dressing manufactured by incorporating a layer of glycosaminoglycans between sheets of ovine forestomach-derived extracellular collagen matrix. It was cleared for marketing (2020) by the FDA 510(k) process for the management of partial and full-thickness wounds, pressure ulcers, venous ulcers, diabetic ulcers, chronic vascular ulcers, tunneled/undermined wounds, surgical wounds (donor sites/grafts, post-Moh's surgery, post-laser surgery, podiatric, wound dehiscence), trauma wounds (abrasions, lacerations, second-degree burns, and skin tears), draining wounds.

Tutopatch® & Tutomesh® Fenestrated Bovine Pericardium are natural collagenous matrices. The material properties of bovine pericardium allow the implants to conform to anatomic structures. It is a biological scaffold intended to be replaced by newly formed connective tissue through remodeling. Tutomesh bovine pericardium is intended for use to reinforce soft tissue where weakness exists in general and plastic surgery applications and is indicated for repair of pericardial structures and for use for surgical repair of soft tissue deficiencies including gastric banding muscle flap reinforcement, repair of rectal prolapse using an abdominal approach,

reconstruction of the pelvic floor using an abdominal approach, and hernias. The typical patient population is adults over the age of 18 who present with soft tissue repair needs.

XCelliStem wound powder is an extracellular matrix composed of porcine collagen. It was cleared for marketing (2018) by the FDA 510(k) process for the management of partial and full-thickness wounds, pressure ulcers, diabetic ulcers, venous ulcers, chronic vascular ulcers, tunneled/undermined wounds, surgical wounds (donor sites/grafts, post-Moh's surgery, post-laser surgery, podiatric, wound dehiscence), trauma wounds (abrasions, lacerations, second-degree burns, and skin tears), and draining wounds. The device is intended for one-time use.

FDA Product codes: KGN, FRO, FTL, FTM.

Living Cell Therapy (Human)

Apligraf® (Organogenesis) is a bilayered living cell therapy composed of an epidermal layer of living human keratinocytes and a dermal layer of living human fibroblasts. Apligraf® is supplied as needed, in 1 size, with a shelf-life of 10 days. In 1998, it was approved by the FDA for use in conjunction with compression therapy for the treatment of noninfected, partial- and full-thickness skin ulcers due to venous insufficiency and in 2001 for full-thickness neuropathic diabetic lower-extremity ulcers nonresponsive to standard wound therapy. FDA product code: FTM.

Corplex P/Theracor P/Allacor P is derived from human umbilical cord extracellular matrix (ECM) and received FDA 510(k) approval in 2024. It is indicated for the management of partial and full-thickness wounds; pressure ulcers; venous ulcers; diabetic ulcers; chronic vascular ulcers; tunneled/undermined wounds; surgical wounds (donor sites/grafts, post-moh's surgery, post-laser surgery, podiatric, wound dehiscence); trauma wounds (abrasions, lacerations, partial-thickness burns, and skin tears); and draining wounds. FDA product code: KGN

DenovoSkin™ is initiated via a small biopsy of healthy skin harvested from the individual. The biopsy is processed to isolate epidermal and dermal cells. The cells are expanded in vitro (can be bio-banked for further use) and thereafter used in combination with a hydrogel for tissue formation.

Dermagraft® (Organogenesis) is composed of cryopreserved human-derived fibroblasts and collagen derived from newborn human foreskin and cultured on a bioabsorbable polyglactin mesh scaffold. Dermagraft has been approved by FDA for repair of diabetic foot ulcers. FDA product code: PFC.

Epicel® (Genzyme Biosurgery) is an epithelial autograft composed of a patient's own keratinocytes cultured ex vivo and is FDA-approved under a humanitarian device exemption for the treatment of deep dermal or full-thickness burns comprising a total body surface area of 30% or more. It may be used in conjunction with split-thickness autografts or alone in patients for whom split-thickness autografts may not be an option due to the severity and extent of their burns. FDA product code: OCE.

mVASC® microvascular tissue is derived from human cadaveric subcutaneous tissue that has been aseptically processed and lyophilized. mVASC is made of small blood vessels and extracellular matrix, inherent non-viable cells, and associated biological signaling factors.

OrCel™ (Forticell Bioscience; formerly Composite Cultured Skin) is an absorbable allogeneic bilayered cellular matrix, made of bovine collagen, in which human dermal cells have been cultured. It was approved by the FDA premarket approval for healing donor site wounds in burn victims and under a humanitarian device exemption (HDE) for use in patients with recessive dystrophic epidermolysis bullosa undergoing hand reconstruction surgery to close and heal wounds created by the surgery, including those at donor sites.

ProgenaMatrix™ is a clear keratin matrix derived from human hair designed to assist wound healing by facilitating a moist wound healing environment. FDA approval was granted for use in dry and exuding partial and full thickness wounds such as: pressure (stage I-IV) and venous stasis ulcers, ulcers caused by mixed vascular etiologies, diabetic ulcers, donor sites and grafts, first and second degree burns, superficial injuries, cuts, abrasions and surgical wounds. ProgenaMatrix™ is not intended to be used on third degree burns. Product code: KGN

TheraSkin® (Soluble Systems) is a cryopreserved split-thickness human skin allograft composed of living fibroblasts and keratinocytes and an extracellular matrix in epidermal and dermal layers. TheraSkin® is derived from human skin allograft supplied by tissue banks compliant with the American Association of Tissue Banks and FDA guidelines. It is considered a minimally processed human cell, tissue, and cellular- and tissue-based product by the FDA.

FDA product codes: FTM, KGN, PFC, OCE, ODS, QCZ.

Biosynthetic Products

Biobrane®/Biobrane-L (Smith & Nephew) is a biosynthetic wound dressing constructed of a silicon film with a nylon fabric partially imbedded into the film. The fabric creates a complex 3-dimensional structure of trifilament thread, which chemically binds collagen. Blood/sera clot in the nylon matrix, adhering the dressing to the wound until epithelialization occurs. FDA product code: FRO.

Hyalomatrix (Anika Therapeutics S.r.l.) is a bilayered, sterile, flexible, and conformable wound dressing that is comprised of a nonwoven pad entirely composed of HYAFF 11, a benzyl ester of hyaluronic acid, and a semipermeable silicone membrane. Hyalomatrix received FDA 510(k) approval (K001508; 2007) for the management of wounds including: partial and full-thickness wounds; second-degree burns; pressure ulcers; venous ulcers; diabetic ulcers; chronic vascular ulcers; tunneled/undetermined wounds; surgical wounds (donor sites/grafts, post-Moh's surgery, post-laser surgery, podiatric, wound dehiscence); trauma wounds (abrasions, lacerations, skin tears); and draining wounds.

Integra® Dermal Regeneration Template (also marketed as Omnigraft Dermal Regeneration Matrix; Integra LifeSciences) is a bovine, collagen/glycosaminoglycan dermal replacement covered by a silicone temporary epidermal substitute. It was approved by the FDA for use in the post-excisional treatment of life-threatening full-thickness or deep partial-thickness thermal injury where sufficient autograft is not available at the time of excision or not desirable because of the physiologic condition of the patient and for certain diabetic foot ulcers. Integra® Matrix Wound Dressing and Integra® Meshed Bilayer Wound Matrix are substantially equivalent skin substitutes and were cleared for marketing by the FDA through the 510(k) process for other indications. Integra® Bilayer Matrix Wound Dressing (Integra LifeSciences) is designed to be used in conjunction with negative pressure wound therapy. The meshed bilayer provides a flexible wound covering and allows drainage of wound exudate. FDA product code: MDD.

PermeaDerm is an FDA approved biosynthetic wound covering product comprised of an adherent and transparent monofilament nylon knitted fabric that is bonded to a thin, silicone membrane, which contains physical slits that are configured to create pores (similar to human skin). FDA code: FRO

- PermeaDerm B (burns) is indicated for use in partial thickness burns, donor sites and coverage of meshed autograft.
- PermeaDerm CW (chronic wounds) is indicated for use with chronic wounds including partial thickness wounds, pressure sores, venous ulcers, diabetic ulcers, chronic vascular ulcers, surgical wounds (donor sites/grafts, post-Moh's, post-laser surgery, podiatric, wound dehiscence, trauma wounds (abrasions, lacerations, second-degree burns, and skin tears) and draining wounds.
- PermeaDerm G (glove) is indicated for use in debrided partial thickness hand burns.

TransCyte™ (Advanced Tissue Sciences) consists of human dermal fibroblasts grown on nylon mesh, combined with a synthetic epidermal layer and was approved by the FDA in 1997. TransCyte is intended as a temporary covering over burns until autografting is possible. It can also be used as a temporary covering for some burn wounds that heal without autografting. Product Code: MGR

FDA product codes: FRO, JXI, MDD, MGR.

Synthetic Products

BTM Wound dressing (NovoSorb BTM [Biodegradable Temporizing Matrix]) is a man-made synthetic polymer composed of a synthetic foam with a polyurethane sealing membrane. It was cleared for marketing by the FDA 510(k) process (2015) for the management of wounds including: partial and full thickness wounds, pressure ulcers, venous ulcers, diabetic ulcers, chronic and vascular ulcers, surgical wounds (donor sites/grafts, post-Moh's surgery, post-laser surgery, podiatric, wound dehiscence), trauma wounds (abrasions, lacerations, second-degree burns, and skin tears) and draining wounds. The device is intended for one-time use.

Microlyte™ Ag (aka Microlyte® Matrix) wound dressing is a sterile, single use unsupported synthetic absorbent polyvinyl alcohol hydrogel sheet with a polymeric surface coating containing ionic and metallic silver. It was cleared for marketing by the FDA 510(k) process (2016) for the management of partial and full thickness wounds including pressure ulcers, venous stasis ulcers, diabetic ulcers, first and second degree burns, abrasions and lacerations, donor sites and surgical wounds. It may be used over debrided and grafted partial thickness wounds.

Mirragen™ Advanced Wound Matrix is composed solely of biocompatible and resorbable borate glass fibers and particulate. It was cleared for marketing (2016) by the FDA 510(k) process for the management of wound types which include: partial and full-thickness wounds, pressure ulcers, venous ulcers, diabetic ulcers, chronic vascular ulcers, tunneled/undermined wounds, surgical wounds (donor sites/grafts, post-Moh's surgery, post laser surgery, podiatric, wound dehiscence), trauma wounds (abrasions, lacerations, first- and second-degree burns, skin tears) and draining wounds. Product code: FRO

Phoenix Wound Matrix is a 3D electrospun synthetic polymer matrix. It was cleared for marketing by the FDA 510(k) process (2018) for the management of partial and full thickness wounds, pressure ulcers, venous ulcers, diabetic ulcers, chronic vascular ulcers,

tunneled/undermined wounds, surgical wounds (donor sites/grafts, post-Moh's surgery, post laser surgery, podiatric, wound dehiscence), trauma wounds (abrasions, lacerations, second degree burns, skin tears) and draining wounds.

Restrata® is made from synthetic biocompatible materials and was designed to include a fibrous structure with high porosity, similar to native extracellular matrix. Restrata® is a porous matrix with a defined rate of resorption that provides a scaffold for cellular infiltration and vascularization before completely degrading via hydrolysis. It was cleared for marketing by the FDA 510(k) process (2020) for the management of partial and full thickness wounds, pressure sores/ulcers, venous ulcers, diabetic ulcers, chronic vascular ulcers, tunneled/undermined wounds, surgical wound (e.g., donor site/ grafts, post-laser surgery, post-Mohs surgery, podiatric wounds, dehisced wounds), trauma wounds (e.g., abrasions, lacerations, partial thickness burns, skin tears), and draining wounds.

Restrata® MiniMatrix is a micronized, electrospun fiber matrix indicated for wound management including surgical and traumatic wounds. FDA approval via a 510(k) process was cleared (2023) for use in the management of wounds, including: Partial and full thickness wounds, pressure sores / ulcers, venous ulcers, diabetic ulcers, chronic vascular ulcers, tunneled / undermined wounds, surgical wounds (e.g., donor site / grafts, post-laser surgery, post-Mohs surgery, podiatric wounds, dehisced wounds), trauma wounds (e.g., abrasions, lacerations, partial thickness burns, skin tears), and draining wounds.

SupraSDRM Bioidegradable Matrix Wound Dressing is fabricated from a tri-polymer of polylactide, trimethylene carbonate, ε-caprolactone and polyvinyl alcohol that can be used either alone or in conjunction with a petroleum jelly and/or gauze wound and burn dressing. It was cleared for marketing by the FDA 510(k) process (2017) for the management of partial and full thickness wounds, pressure (stage I and IV) and venous ulcers, ulcers caused by mixed vascular etiologies, venous stasis and diabetic ulcers, 1st and 2nd degree burns, partial thickness burns, cuts and abrasions, acute wounds, trauma wounds, surgical wounds, superficial wounds, grafted wounds and donor sites.

Suprathel® (PolyMedics Innovations) is a synthetic copolymer membrane fabricated from a tripolymer of polylactide, trimethylene carbonate, and s-caprolactone. It is used to provide temporary coverage of superficial dermal burns and wounds. Suprathel® is covered with gauze and a dressing that is left in place until the wound has healed. FDA 510(k) approval was granted in 2009. Product code: FRO

Nerve Wraps

AxoGuard® nerve connector (Axogen, Inc) is an implant derived from small intestine submucosa designed to protect injured and compressed nerves. Other FDA 510K approved nerve wraps include: Flexible Collagen Nerve Cuff (Collagen Matrix, Inc), Mochida Nerve Cuff (Mochida Pharmaceutical Co.), NervAlign Nerve Cuff (Renerve, Ltd), Nerve tape (BioCircuit Technologies, Inc), Neurawrap (Integra LifeSciences, Corp), NeuroMend (Stryker Orthopedics), NeuroShield (Monarch bioimplants, GmbH), Reinforce flexible Collagen Nerve Cuff (Collagen Matrix, Inc), and Versawrap nerve protector (Alafair Biosciences, Inc). FDA product code: JXI.

Flexible Collagen Nerve Cuff (Collagen Matrix, Inc) is bovine tendon used for the management of peripheral nerve injuries in discontinuities where gap closure can be achieved by flexion of the extremity (e.g., to prevent ingrowth of scar tissue) or at the end of the nerve in the foot to

reduce the formation of symptomatic or painful neuroma. FDA 510(k) approval was granted in 2014 (K131541).

Mochida Nerve Cuff (Mochida Pharmaceutical Co.) is composed of sodium alginate (a polysaccharide derived from seaweed) and polyglycolic acid nonwoven fabric. FDA 510(k) approval was granted in 2024. Mochida Nerve Cuff is indicated for the repair of peripheral nerve discontinuities where gap closure can be achieved by flexion of the extremity, or the management of peripheral nerve injuries in which there has been no substantial loss of nerve tissue. FDA product code: JXI.

NervAlign Nerve Cuff (Renerve, Ltd) is a collagen membrane matrix derived from porcine pericardium which received FDA 510(k) clearance in 2022. NervAlign® Nerve Cuff is indicated for the repair of peripheral nerve injuries in which there is no gap or where a gap closure is achieved by flexion of the extremity.

Nerve Tape (BioCircuit Technologies, Inc.) is composed of a bioabsorbable, extracellular collagen matrix derived from porcine small intestinal submucosa, FDA 510(k) approval was granted in 2022 for the repair of peripheral nerve discontinuities where gap closure can be achieved by flexion of the extremity.

NeuraWrap™ (Integra LifeSciences, Corp) is an absorbable collagen implant that provides a nonconstricting encasement for injured peripheral nerves for protection of the neural environment. In 2004, NeuraWrap received FDA 510(k) approval for the management of peripheral nerve injuries in which there has been no substantial loss of nerve tissue.

NeuroShield (Monarch bioimplants, GmbH) is a chitosan (found in the exoskeletons of crustaceans like shrimp, crabs, and lobsters) polysaccharide membrane indicated for the repair of peripheral nerve injuries by providing a protective barrier during tissue healing. FDA approval 510(k) was granted in 2019. NeuroShield™ is indicated for the repair of peripheral nerve injuries in which there is no gap or where a gap closure can be achieved by flexion of the extremity.

Reinforced Flexible Collagen Nerve Cuff (Collagen Matrix, Inc) is a resorbable, flexible type I collagen tubular matrix circumferentially supported with a resorbable synthetic polymer filament. FDA 510(k) approval was granted (2017) for the management of peripheral nerve injuries in discontinuities where gap closure can be achieved by flexion of the extremity (e.g., to prevent ingrowth of scar tissue).

VersaWrap (Alafair Biosciences, Inc) is a plant-based (non-tissue, non-collagenous) bioresorbable hydrogel which received FDA 510(k) approval in 2020. VersaWrap Nerve Protector is indicated for the management of peripheral nerve injuries in which there has been no substantial loss of nerve tissue.

FDA product codes: JXI

Devices, Kits and Systems used for Autologous Cell Preparation

Recell® (Avita Medical) was initially approved by the FDA in September 2018 under the premarket approval (PMA) process (PMA BP170122). It is an autologous cell harvesting device indicated for the treatment of acute partial-thickness thermal burn wound when used by an appropriately-licensed healthcare professional at the patient's point of care to prepare

autologous RES Regenerative Epidermal Suspension. The initial indication was for use in patients 18 years of age and older in combination with meshed autografting. Subsequently, indications were expanded to include direct application to acute partial-thickness thermal burn wounds in patients 18 years of age and older or application in combination with meshed autografting for acute full-thickness thermal burn wounds in pediatric as well as adult patients and for and full-thickness skin defects after traumatic avulsion (e.g., degloving) or surgical excision (e.g., necrotizing tissue infection) or resection (e.g., skin cancer) in patients 15 years of age and older.

FDA product code: QCZ.

Government Regulations

National:

In 2019, CMS reported that it is finalizing the proposal to continue the policy established in calendar year 2018 to assign skin substitutes to the low cost or high-cost group.(78) In addition, CMS presented several payment ideas to change how skin substitute products are paid and solicited comments on these ideas to be used for future rulemaking. In 2022, CMS proposed changing the terminology of skin substitutes to "wound care management products", and to treat and pay for these products as incident to supplies under the Physician Fee Schedule beginning on January 1, 2024. However, in November 2022, CMS posted this update on the process: "After reviewing comments on the proposals, we understand that it would be beneficial to provide interested parties more opportunity to comment on the specific details of changes in coding and payment mechanisms prior to finalizing a specific date when the transition to more appropriate and consistent payment and coding for these products will be completed. We plan to conduct a Town Hall in early CY 2023 with interested parties to address commenters' concerns as well as discuss potential approaches to the methodology for payment of skin substitute products under the PFS. We will take into account the comments we received in response to CY 2023 rulemaking and feedback received in association with the Town Hall in order to strengthen proposed policies for skin substitutes in future rulemaking."(79)

Porcine Skin and Gradient Pressure Dressings Pub 100-3, Ch 4. Rev. 198, 6/29/17; (270.5); Rev. 1, 10/3/03. Longstanding national coverage determination. Effective date has not been posted.

Indications and Limitations of Coverage

Porcine (pig) skin dressings are covered, if reasonable and necessary for the individual patient as an occlusive dressing for burns, donor sites of a homograft, and decubiti and other ulcers.(73)

Local:

LCD: Skin Substitute Grafts/Cellular and Tissue-Based Products for the Treatment of Diabetic Foot Ulcers and Venous Leg Ulcers. L39865. Effective date: January 1, 2026.

Note: At the time of review, this is a future effective date for a New LCD. Please check the LCD as the effective date has changed on multiple occasions.

Application of skin substitute graft/CTP for ulcer care indications other than DFU or VLU are not addressed by this LCD. Use of skin substitute graft/CTP must meet the reasonable and necessary threshold for coverage and these products must be used in accordance with their intended use as approved/regulated by the United States (U.S.) Food and Drug Administration (FDA).

Depending on the purpose of the product and its proposed functions, skin substitute graft/CTP are regulated by the FDA premarket approval (PMA) process, FDA 510(k) premarket notification process, or the FDA regulations for human cells, tissues, and cellular and tissue-based products (HCT/Ps). A product with proposed benefit to chronic ulcer healing does not assume the designation of a skin substitute graft/CTP. FDA classification and indication are not the sole determinants of designation as a skin substitute graft/CTP or provide the reasonable and necessary threshold for coverage.

A DFU or VLU having failed to respond to standard of care treatment after 4 weeks (28 days) may be considered chronic and the addition of a skin substitute graft /CTP may be considered reasonable and necessary for certain patients.

The medical record documentation must support the medical necessity for skin replacement therapy and the product's use as an ulcer treatment, other than as a wound dressing or covering.

Covered Indications

If the patient meets all criteria as outlined in this LCD, application of a skin substitute graft/CTP in the treatment of DFU and VLU is considered reasonable and necessary:

1. The presence of a chronic, non-infected DFU having failed to achieve at least 50% ulcer area reduction with documented standard of care (SOC) treatment (outlined below) for a minimum of 4 weeks with documented compliance.
2. The presence of a chronic, non-infected VLU having failed to respond to documented SOC treatment (outlined below) for a minimum of 4 weeks with documented compliance.
 - For purposes of this LCD, SOC treatment includes:
 - Comprehensive patient assessment (history, exam, vascular assessment) and diagnostic tests indicated as part of the implemented treatment plan.
 - For patients with a DFU: assessment of Type 1 or Type 2 diabetes and management history with attention to certain comorbidities (e.g., vascular disease, neuropathy, osteomyelitis), review of current blood glucose levels/hemoglobin A1c (HbA1c), diet and nutritional status, activity level, physical exam that includes assessment of skin, ulcer, and vascular perfusion), and assessment of off-loading device or use of appropriate footwear.
 - For patients with a VLU: assessment of clinical history (that includes prior ulcers, higher body mass index, history of pulmonary embolism or superficial/deep venous thrombosis, higher number of pregnancies, and physical inactivity), physical exam (edema, skin changes and vascular competence*), evaluation of superficial or deep venous reflux, perforator incompetence, and chronic (or acute) venous thrombosis. The use of a firm strength compression garment (>20 mmHg) or multi-layered compressive dressings is an essential component of SOC for venous stasis ulcers.

3. An implemented treatment plan to be continued throughout the course of treatment demonstrating all the following:
 - Debridement as appropriate to a clean granular base.
 - Documented evidence of offloading for DFU and some form of sustained compression dressings for VLU.
 - Infection control with removal of foreign body or nidus of infection.
 - Management of exudate with maintenance of a moist environment (moist saline gauze, other classic dressings, bioactive dressing, etc.).
 - Documentation of smoking history, and counselling on the effect of smoking on wound healing. Treatment for smoking cessation and outcome of counselling, if applicable.
4. The skin substitute graft/CTP is applied to an ulcer that has failed to heal or stalled in response to documented SOC treatment. Documentation of response requires measurements of the initial ulcer, pre-SOC ulcer measurements, weekly SOC ulcer measurements, post-completion SOC ulcer measurements following (at least) 4 weeks of SOC, ulcer measurements at initial placement of the skin substitute graft/CTP, and before each subsequent placement of the skin substitute graft/CTP. Failure to heal or stalled response despite SOC measures must have preceded the application for a minimum of 4 weeks and must continue for the course of therapy. Continuous compression therapy for VLU must be documented for the episode of care.
5. The medical documentation must include the interventions which failed during prior ulcer evaluation and management. The record must include an updated medication history, review of pertinent medical problems diagnosed since the previous ulcer evaluation, and explanation of the planned skin replacement with choice of skin substitute graft/CTP product. The procedure risks and complications must also be reviewed and documented.
6. The patient is under the care of a qualified provider for the treatment of the systemic disease process(es) etiologic for the condition (e.g., venous insufficiency, diabetes, neuropathy) and documented in the medical record.

Coverage requirements for skin substitute grafts/CTP

To qualify as skin substitute graft/CTP the product must be:

- A non-autologous human cellular or tissue product (e.g., dermal or epidermal, cellular and acellular, homograft **OR** allograft), **OR** non-human cellular and tissue product (i.e., xenograft), **OR** biological product (synthetic or xenogeneic) applied as a sheet, allowing scaffold for skin growth, intended to remain on the recipient and grow in place or allow recipient's cells to grow into the implanted graft material **AND**
- Supported by high-certainty supporting evidence to demonstrate the product's safety, effectiveness, and positive clinical outcomes in the function as a graft for DFU and/or VLU. Substantial equivalence to predicate products does not allow sufficient evidence to support similar cleared products.

Note: Liquid or gel preparations are not considered grafts. Their fluidity does not allow graft placement and stabilization of the product on the wound.

The following are considered reasonable and necessary:

- The maximum number of applications of skin substitute graft/CTP within the episode of skin replacement therapy (defined as 12 to 16 weeks from the first application of a skin

substitute graft/CTP) is 8 applications. The mean number of applications associated with complete wound healing is 4; however with documentation of progression of wound closure under the current treatment plan and medical necessity for additional applications, up to 8 applications may be allowed. Use of greater than 4 applications requires an attestation from the provider showing that the requirements specified in the LCD have been met and the additional applications are medically necessary. In absence of this attestation, denial of the additional applications will occur. Please refer to the Billing and Coding article for instruction on reporting applications 5 to 8.

- The usual episode of care for skin substitute graft/CTP is 12 weeks; however, some wounds may take longer to heal. An additional 4 weeks will be allowed, totaling 16 weeks from initial application, with documentation that includes progression of wound closure under current treatment plan.
- The skin substitute graft/CTP must be used in an efficient manner utilizing the most appropriate size product available at the time of treatment. Excessive wastage (discarded amount) should be avoided by utilization of size appropriate packaging of the product consistent with wound size. The graft must be applied in a single layer without overlay of product or adjacent skin in compliance with the correct label application techniques for the skin substitute graft/CTP.
- Only skin substitute grafts/CTP with labeled indications for use over exposed muscle, tendon or bone can be used in these cases and only in the absence of contraindications (e.g., infected, ischemic, or necrotic wound bed).

Limitations

The following are considered not reasonable and necessary:

- Greater than 8 applications of a skin substitute graft/CTP within an episode of care (up to 16 weeks).
- Repeat applications of skin substitute graft/CTP when a previous application was unsuccessful. Unsuccessful treatment is defined as an increase in size or depth of an ulcer, no measurable change from baseline, and no sign of significant improvement or indication that significant improvement is likely (such as granulation, epithelialization, or progress towards closure).
- Application of skin substitute graft/CTP in patients with inadequate control of underlying conditions or exacerbating factors, or other contraindications (e.g., active infection, progressive necrosis, active Charcot arthropathy of the ulcer extremity, active vasculitis, ischemia).
- Use of surgical preparation services (e.g., debridement), in conjunction with routine, simple or repeat skin replacement therapy with a skin substitute graft/CTP.
- All liquid or gel skin substitute products or CTPs for ulcer care.
- Placement of skin substitute graft/CTP on infected, ischemic, or necrotic wound bed.

Surgical Dressings (L33831) for services performed on or after 1/1/2024

Collagen Dressing Or Wound Filler (A6010, A6011, A6021-A6024)

A collagen-based dressing or wound filler is covered for full thickness wounds (e.g., stage 3 or 4 ulcers), wounds with light to moderate exudate, or wounds that have stalled or have not progressed toward a healing goal. They can stay in place up to 7 days. Collagen based dressings are not covered for wounds with heavy exudate, third-degree burns, or when an active vasculitis is present.

Application of Bioengineered Skin Substitutes (L34593) for services performed on or after 1/1/16 (Retired 3/1/16)

This LCD covers the use of skin substitutes and related products in the treatment of lower extremity ulcer disease. The LCD does not pertain or otherwise apply to the use of any skin substitutes or related products in the treatment of burns, skin cancer, or for true reconstructive surgery.

Indications

Application of bioengineered skin substitutes will be covered when the following conditions are met and documented as appropriate for the individual patient:

1. Presence of neuropathic diabetic foot ulcers for greater than four (4) weeks duration
2. Presence of venous stasis ulcers of greater than (1) one month duration that have failed to respond to documented conservative measures for greater than one (1) month duration
3. Presence of neuropathic diabetic foot ulcers that have failed to respond to documented conservative measures for greater than one (1) month duration. These measures must include appropriate steps to off-load pressure during treatment.
4. Presence of partial or full-thickness ulcers
5. Measurements of the initial ulcer size, the size following cessation of any conservative management and the size at the beginning of skin substitute treatment.

In all cases, the ulcer must be free of infection and underlying osteomyelitis. Documentation must be provided that these conditions have been successfully treated, resolved, prior to instituting skin substitute treatment.

Medicare accepts the Federal Drug Administration's (FDA) classification and description of any bioengineered skin substitute. Application of a Bioengineered Skin Substitute is covered when the following conditions are met and documented as appropriate for the individual patient:

1. Beneficiaries with diabetes under current medical management and controlled with stable HgbA1c level.
2. Venous stasis ulcers that have failed to heal, using conservative measures.
3. Neuropathic diabetic foot ulcers that have failed to heal, using conservative measures.
4. Ulcers that, do not involve tendon, muscle or joint capsule, or have bone exposure, extend through the dermis Unless specifically indicated within the FDA approved package insert.
5. Beneficiaries with adequate arterial blood supply to the foot evidenced by a palpable pulse on the foot (either dorsalis pedis or posterior tibial artery) or an Ankle Brachial Index (ABI) of 0.65 or greater.
6. Neuropathic diabetic foot ulcers that have been treated with appropriate steps to off-load pressure.
7. The ulcer must be free of infection and underlying osteomyelitis.

The following SKIN Substitutes are currently covered under Medicare in an inpatient hospital, outpatient hospital, ambulatory surgical center, or office setting:

- Q4101 Skin substitute, apligraf, per square centimeter
- Q4102 Skin substitute, oasis wound matrix, per square centimeter
- Q4106 Skin substitute, dermagraft, per square centimeter
- Q4107 Graftjacket, per square centimeter
- Q4110 Skin substitute, primatrix, per square centimeter

Q4121 Theraskin per square centimeter

Q4131 EpiFix per square centimeter

Future LCA

Billing and Coding: Skin Substitutes Grafts/Cellular Tissue-Based Products for the Treatment of Diabetic Foot Ulcers and Venous Leg Ulcers. Anticipated Effective Date: Jan 1, 2026.

Refer to website for details.(128)

(The above Medicare information is current as of the review date for this policy. However, the coverage issues and policies maintained by the Centers for Medicare & Medicare Services [CMS, formerly HCFA] are updated and/or revised periodically. Therefore, the most current CMS information may not be contained in this document. For the most current information, the reader should contact an official Medicare source.)

Related Policies

Amniotic Membrane and Amniotic Fluid

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The articles reviewed in this research include those obtained in an Internet based literature search for relevant medical references through 5/14/25, the date the research was completed.

Joint BCBSM/BCN Medical Policy History

Policy Effective Date	BCBSM Signature Date	BCN Signature Date	Comments
11/01/06	8/30/06	9/18/06	Joint policy established
3/1/07	12/28/06	1/15/07	Policy updated with new FDA-approved items.
5/1/08	2/19/08	5/1/08	Routine maintenance
11/1/09	8/18/09	8/18/09	Maintenance, new codes added
11/1/10	8/17/10	8/17/10	Maintenance, new code added
9/1/11	6/21/11	6/21/11	Policy updated with new codes; J codes removed; added Q4117-Q4121, G0440-G0441, 15330-15336, 15430,15431; nomenclature revised for codes Q4101-Q4115 to remove "skin substitute" from the descriptors; Flex HD® added to list of human derived tissue; added Medicare criteria to Inclusions relative to diabetic wounds.
11/1/12	7/30/12	7/30/12	Policy updated with new codes effective 1/1/12: 15271-15278, C9366-C9369, Q4122- Q4130; Theraskin (Q4121) and GraftJacket (Q4107) added as approved human tissue products; deleted codes 15170-15175, 15330-15336, 15340-15341, 15360-15366,15400-15401,15420-15421, 15430-15431, C9365, G0440, G0441.
11/1/13	8/20/13	9/3/13	Codes added to policy: 15777, Q4126, Q4131-Q4136, A6010-A6011, C9356, C9358, C9360 and C9364; Medical Policy Statement and Inclusion section revised to reflect EpiFix as established.
3/1/15	12/12/14	12/29/14	Routine maintenance; added codes A6021-A6023; updated CMS information
7/1/15	4/24/15	5/8/15	Codes added: Q4137-Q4160
7/1/16	4/19/16	4/19/16	Routine maintenance Added codes: Q4161-Q4165

			Moved codes Q4147 Q4149 and Q4158 under covered codes Removed C codes from policy
3/1/17	12/13/16	12/13/16	• Routine maintenance • Continues to diverge from BCBSA - No similarities • Codes added: Q4166-Q4175 Deleted codes: Q4118-Q4120, Q4129
5/1/17	5/9/17	5/9/17	• Continues to diverge from BCBSA except: - Moved codes Q4132 and Q4133 to “established” section of HCPCS codes for Grafix products to mirror BCBSA determination.
7/1/18	3/20/18	3/12/18	• Routine maintenance • Codes added: C9358 and C9360 • Deleted Unite Biomatrix – no longer available • Codes added Q4176-Q4182 Policy rewrite to cover BCBSA indications, and FDA and CMS approved products
3/1/19	12/11/18		• Routine maintenance Amniotic products and codes removed from policy (Grafix, EpiFix, amnioband, neox, woundEx, palinGen); new policy written
3/1/20	12/17/19		• Routine maintenance • Codes added as investigational: Q4193, Q4197, Q4200, Q4202, Q4220, Q4222, Q2226 • Codes added as Established – FDA approved: Q4195, Q4196, Q4203 Q4172 deleted – per AMA
11/1/20	8/18/20		• Routine maintenance

11/1/21	8/17/21		• Routine maintenance • Products cross checked and added to Incl and Excl based on FDA approval, BCBSA coverage or Medicare coverage.
11/1/22	8/16/22		• Routine maintenance • Inclusions updated with FDA approved products
3/1/23	12/20/22		• Off schedule review for code update: added A2014, A2015, A2016, A2017, A2018 • Nomenclature update to Q4128 (Matrix HD removed) (slp)
11/1/23	8/15/23		• Routine maintenance (slp) • Vendor managed: N/A • Code update – NeoMatrix added as EST (A2021); Kerecis Omega3 Marigen (A2019) and AC5 Advance wound system (A2020) added as EI • Recell and Ac5 added as EI • Clarification added to cross reference FDA approved products with regulatory section for specified uses
11/1/24	8/20/24		• Routine maintenance (slp) • Vendor managed: N/A • DeNovoSkin, Tutomesh Fenestrated Bovine Pericardium added as EI • ProgenaMatrix (Q4222) moved from EI to EST • mVASC and Restrata MiniMatrix (A2026) added as EST • WPS issued proposed LCD • OviTex® PRS Long Term Resorbable and Ovine Tissue Matrix added as EST – FDA approved
5/1/25			• Policy pulled
11/1/25	8/29/25		• Routine review (slp) • Vendor managed: N/A

			• Removed FDA language • LCD added for tx of diabetic foot and venous leg ulcers and for “Surgical Dressings” • Products added as EI include: ○ Derm-maxx (Q4238), Endoform® Reconstructive Template – Non-Absorbable (aka: OviTex IHR Reinforced Tissue Matrix; OviTex LPR Reinforced Tissue Matrix; OviTex Reinforced Tissue Matrix with Permanent Polymer [OviTex]), Endoform Reconstructive Template (aka OviTex Reinforced Tissue Matrix with Resorbable Polymer), Resolve Matrix, MiroDry Wound Matrix, Myriad Particles, Foundation DRS Solo, Miro3D Wound Matrix, Miro3D Flex, Mochida Nerve Cuff; NervAlign Nerve Cuff; Nerve Tape, NeuroShield, Versawrap nerve protector, Myriad Matrix, Myriad Morcells, Myriad Morcells Fine, Reinforced Bioscaffolds. • Codes added to policy include: ○ 15011-15018 (EST) ○ A2024, A2025, A2030, A2031, A2032, A2033, A2034, C8002, C9361 (EI) • Formatting updated
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Next Review Date: 3rd Qtr, 2026

BLUE CARE NETWORK BENEFIT COVERAGE
POLICY: SKIN AND TISSUE SUBSTITUTES

I. Coverage Determination:

Commercial HMO (includes Self-Funded groups unless otherwise specified)	Covered, criteria apply
BCNA (Medicare Advantage)	Refer to the Medicare information under the Government Regulations section of this policy
BCN65 (Medicare Complementary)	Coinsurance covered if primary Medicare covers the service

II. Administrative Guidelines:

- The member's contract must be active at the time the service is rendered.
- Coverage is based on each member's certificate and is not guaranteed. Please consult the individual member's certificate for details. Additional information regarding coverage or benefits may also be obtained through customer or provider inquiry services at BCN.
- The service must be authorized by the member's PCP except for Self-Referral Option (SRO) members seeking Tier 2 coverage.
- Services must be performed by a BCN-contracted provider, if available, except for Self-Referral Option (SRO) members seeking Tier 2 coverage.
- Payment is based on BCN payment rules, individual certificate and certificate riders.
- Appropriate copayments will apply. Refer to certificate and applicable riders for detailed information.
- CPT - HCPCS codes are used for descriptive purposes only and are not a guarantee of coverage.