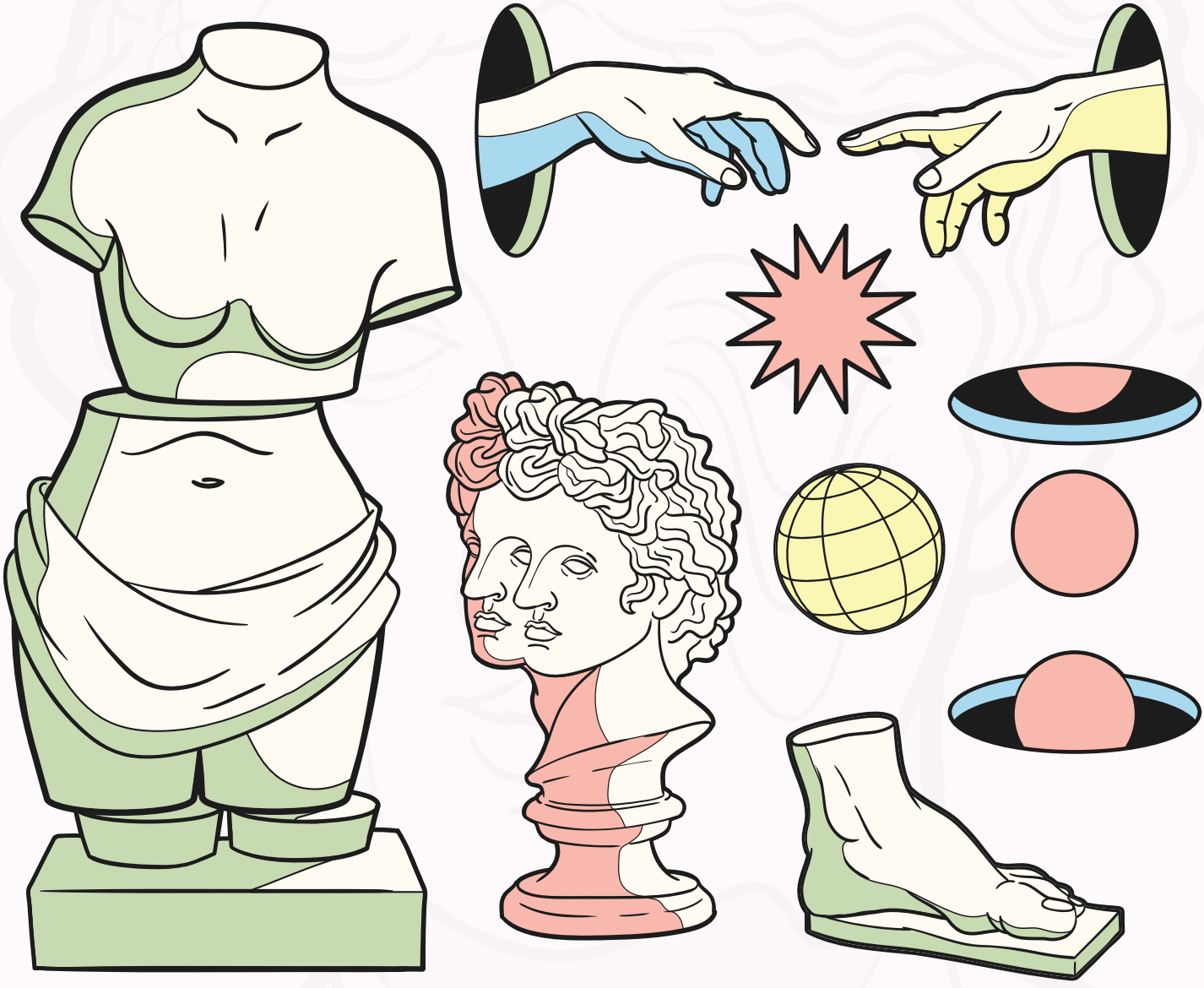
JWC International Position Document



Cellular, acellular, and matrix-like products (CAMPs)

for soft-tissue reconstruction in acute surgical and traumatic wounds

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Declarations of interest
The authors have no conflicts of interest to declare.

Introduction

Cellular, acellular and matrix-like products (CAMPs) are intended to promote the repair and regeneration of injured tissue by supporting changes in wound-healing physiology through intercellular and intracellular communication and matrix production. The use of placental-based products for wound healing was pioneered in the early 1900s[1,2] and has been part of plastic surgery for over a century. Since the 1990s, these products have been used in the repair of a myriad of tissue defect types, including both acute and hard-to-heal wounds, as well as surgical wounds across multiple specialities and procedures.[3,4] More recently, several other human and animal tissue-derived or engineered materials have been employed to support improved wound healing in the acute setting.

The term 'CAMPs' was introduced in a *Journal of Wound Care* (JWC) International Consensus Document on best practice for wound repair and regeneration, based on an expert panel meeting held in July 2022.[5] The panel reached a consensus that it should replace outdated terms, such as skin substitutes, skin equivalents and cellular/tissue products, as they did not adequately capture the full extent of currently available products, nor the mechanisms by which these products facilitate wound healing. The consensus document defined CAMPs as 'a broad category of biomaterials, synthetic materials or biosynthetic matrices that support repair or regeneration of injured tissues through various mechanisms of action'.[6] The document also provided guidelines on best practice for using CAMPs, intended for all members of multidisciplinary wound-care teams, including all advanced practice practitioners (physicians of all specialties, nurse practitioners, physician assistants, physical therapists and occupational therapists).

Since the publication of the consensus document,[5] the term 'CAMPs' has become widely accepted in wound care, and it is being used with increasing consistency in peer-reviewed publications, academic presentations and other clinical discussions on wound care. However, as of December 2024, the US Centers for Medicare and Medicaid Services (CMS) have not yet adopted the term for coding purposes, despite recognising it in the latest future effective local coverage determination (LCD) document, which addresses the use of CAMPs in diabetic foot ulcers (DFUs) and venous leg ulcers (VLUs).[7]

Consensus statement: The term 'CAMPs' should be used across all disciplines and specialties to ensure greater consistency in development and implementation of best practice, as well as more homogeneity in research.

The US Food and Drug Administration (FDA) offers three pathways for commercial marketing of CAMPs (*Table 1*).[8]

This JWC Position Document is based on the conclusions of a panel meeting convened on 16 October 2024 in Las Vegas, Nevada, US. It is intended to complement the earlier International Consensus Document on CAMPs, with a specific focus on soft-tissue reconstruction in acute surgical and traumatic wounds. The panel explored emerging knowledge and current clinical practice needs through a literature review of recently reported uses of CAMPs in specialism and diagnoses relevant to soft-tissue reconstruction in acute surgical and traumatic wounds. Discussion of the reviewed literature, combined with expert opinion, resulted in a consensus on best-practice recommendations for integrating CAMPs into surgical patients' care plans. These recommendations aim to provide guidance on overcoming implementation barriers, improving clinical practice, and enhancing patient outcomes. Where possible, these recommendations have been referenced to supporting literature, while those based on the panel's expert opinion are presented as consensus statements.

Table 1. Avenues of Food and Drug Administration approval for marketing

Route and eligibility	Process	Examples
Pre-market approval New devices with high safety risks	Independent demonstration that the device: is life-supporting or -sustaining; is substantially important in preventing impairment of human health; or presents no unreasonable risk of illness or injury (the most rigorous route).	• Apligraf (Organogenesis, Canton, MA, US) • Dermagraft (Organogenesis, Canton, MA, US) • Integra Dermal Regeneration Template (Integra LifeSciences, Princeton, NJ, US) • Omnigraft Dermal Regeneration Matrix (Integra LifeSciences, Princeton, NJ, US)
510(k) clearance New devices with low-to-moderate safety risks	Comprehensive safety and efficacy review of scientific, pre-clinical and clinical data to determine the device is substantially equivalent to a legally marketed device (FDC Act section 513i1A).	• Miro3D Wound Matrix (Reprise Biomedical, Plymouth, MN, US) • Myriad Matrix (Aroa Biosurgery, Auckland, NZ) • Oasis (Smith+Nephew, Watford, UK) • PuraPly AM (Organogenesis, Canton, MA, US)
Public Health Services Act section 361 Human cells, tissues or cellular or tissue-based products	Auditable registration of compliance with CFR 1271 regulations and CFR 1271.10(a) criteria to ensure safety for human use without requiring pre-market approval or 510(k) clearance.	• Affinity (Organogenesis, Canton, MA, US) • Grafix (Smith+Nephew, Watford, UK) • EpiFix (Mimedx, Marietta, GA, US)

Recent reported uses of CAMPs by specialism or diagnosis

In recent years, numerous publications have reported positive results from the use of CAMPs for soft-tissue reconstruction in acute surgical and traumatic wounds across a wide range of specific diagnoses. To explore this trend, a literature search was conducted for papers published that included at least one search term for a relevant diagnosis or specialty and at least one search term for CAMPs, either as a general umbrella category (e.g., skin equivalents, cellular/tissue products, biologic dressings) or specific CAMP categories (e.g., amniotic membrane). The primary databases searched were PubMed, Google Scholar and ScienceDirect. The search was generally limited to papers published in the past 5 years, although some older papers have been included where particularly relevant to the discussion.

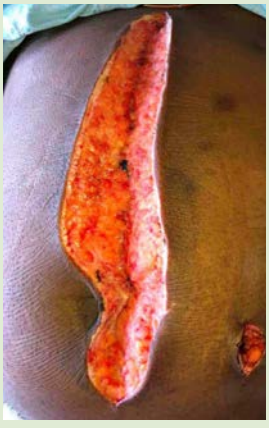
The following discussion presents an exemplary but not exhaustive selection of these cases, organised by specialism or diagnosis, to encourage reflection on scenarios where patient outcomes may be improved with the use of CAMPs to support closure of soft-tissue defects. These publications show surgeons and wound specialists across multiple disciplines using CAMPs in creative, innovative ways to obtain optimal results for wound closure. Together, these studies demonstrate that wound care is not confined to just one specialty, and they show how success, particularly in managing complex acute wounds that may transition to hard-to-heal wounds, requires active collaboration from all participants in a patient's medical care.

Consensus statement: While the majority of these publications are case studies, future research on CAMPs would benefit from more randomised controlled trials (RCTs), although appropriate RCTs for surgery can be difficult to structure.

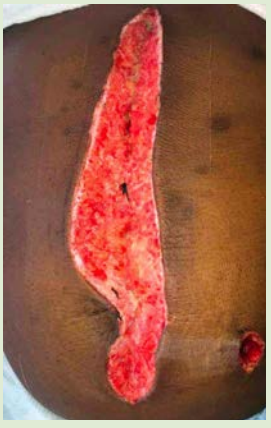
Case study 1. Abdominal stab wound reconstructed with cryopreserved placental membrane

Courtesy of Zachary Bauman

A 29-year-old man presented with a 34x4.5x2 cm open abdominal stab wound. He was obese, had diabetes mellitus and smoked. He underwent emergency exploratory laparotomy-splenectomy, hepatorrhaphy and diaphragm injury repair, after which the skin was left open, with negative pressure wound therapy (NPWT). After 4 days, there was minimal wound healing, but the patient was ready for discharge from hospital. Four pieces of cryopreserved placental membrane were applied at the bedside, along with NPWT. After 2 days, there was significant granulation tissue development in the wound bed. NPWT was removed, the wound underwent delayed primary closure and the patient was discharged the same day. The patient's wound continued to improve in the outpatient setting.



Before application

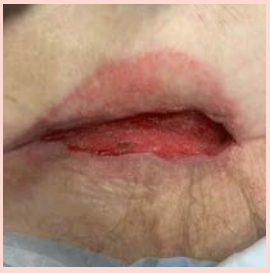


Day 2

Case study 2. Abdominal surgical dehiscence reconstructed with three-dimensional hepatic porcine acellular matrix

Courtesy of Moses K Shieh

A woman presented with a dehisced abdominal surgical wound 10 weeks after undergoing panniculectomy surgery. The wound measured 8x2x0.5 cm and included 2 cm of medial tunnelling. A three-dimensional porcine hepatic acellular matrix was applied at the initial presentation and again at day 3. The wound showed consistent reduction in size over time and was completely healed by day 127.



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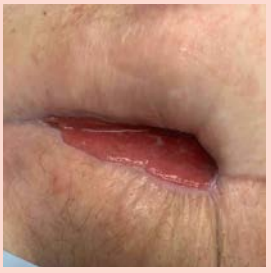
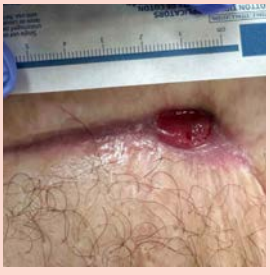


Day 10



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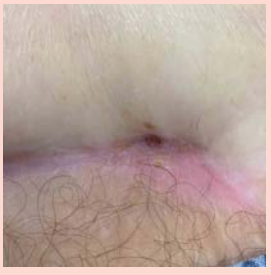
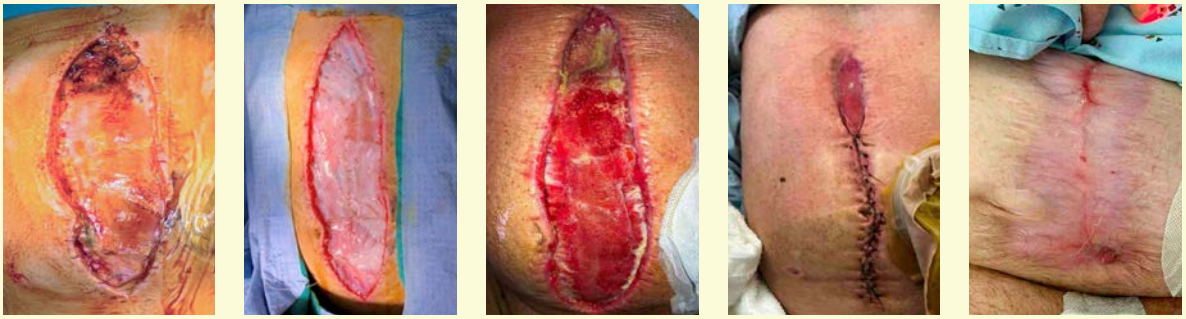


Day 127

Case study 3. Abdominal trauma reconstructed with cryopreserved umbilical tissue

Courtesy of Zachary Bauman

A 56-year-old man presented with an open abdominal surgical wound. The wound was created following complex surgery 2 weeks previously for abdominal trauma after a truck he was working on fell and rolled over his pelvis. He had experienced cardiac arrest (return of spontaneous circulation after 5 minutes), bladder rupture with avulsion of urethra (bladder repair and catheter placement), complete avulsion of rectum (stapled off sigmoid colon), open book pelvic fracture (stabilised with traction pin) and several perineal lacerations that were irrigated. After 2 days, he underwent end colostomy, abdominal wall closure and application of negative pressure wound therapy (NPWT). After 2 postoperative weeks without good granulation tissue development, cryopreserved umbilical tissue (CUT) was applied. At week 2 post-CUT, the wound had progressed with significant granulation. At week 3, a skin flap was created, and the wound was 85% closed. Complete closure was achieved at week 7.



Presentation | CUT | Week 2 | Week 3 | Week 7

Abdominal wounds and chest-wall reconstruction

CAMPs have been used as part of multi-stage treatment of complex open abdominal wounds (*Case studies 1–3*), including those involving enterocutaneous fistulas,[9] ostomy reconstruction,[10] abdominal defects with extruding bowel[11] and trauma with abdominal injuries.[12,13]

A 2024 retrospective review by Sweitser et al reported that reinforced biologic meshes are more commonly used if there has been a previous repair, and extra reinforcement of already traumatised abdominal-wall tissue is needed. The CAMPs are used to promote granulation over the exposed structures, sometimes in conjunction with negative pressure wound therapy (NPWT), with final closure achieved with a split-thickness skin graft (STSG) or closure by primary intention.[14]

The use of matrix-like products in conjunction with surgical procedures for chest-wall reconstruction has been reported for both adults[15–18] and paediatric patients[19] with lower infection rates, good chest-wall stability and no paradoxical movements. Cadaveric allografts for sternochondral replacement in anterior chest-wall reconstruction has been shown to be safe with long-term optimal chest-wall stability and no complications.[20,21,13]

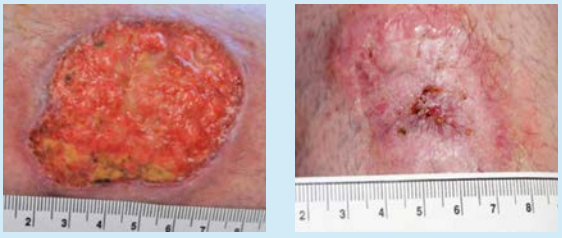
Burns

CAMPs can serve as temporary coverage for burns (*Case studies 4–6*), as well as to facilitate re-epithelialisation for permanent coverage.[22,23] When used on a clean debrided burn site, they can improve wound coverage; restore functional and aesthetic skin qualities; help prevent wound infection; maintain a moist wound environment; and prevent fluid loss.[23]

Case study 4. Full-thickness burn reconstructed with a synthetic polymeric matrix[22]

Courtesy of Sarah W Manning

A 43-year-old woman presented with a 24.1 cm^2 full-thickness burn, which had not healed for 5 weeks despite treatment with silver sulfadiazine, an iodine absorbent pad and a silver-foam dressing. A synthetic polymeric matrix was applied weekly, covered with a gauze dressing. The wound area decreased steadily over the following weeks, reducing by 38% to 15 cm^2 by week 3 and fully healing by week 12.



Presentation | Week 12

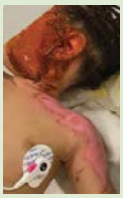
A 2024 comprehensive review by Kenny et al of dressings used for temporary and permanent coverage of burns included a detailed discussion of the allografts,[24] xenografts[25,26] and other CAMPs used in burn therapy, while acknowledging that autografts remain the core of burn reconstruction. It was noted that the CAMPs used for restoration of dermal and epidermal structures did not have the ability to restore adnexal structures.[27]

Two 2022 cases by Al Mousa et al described facial thermal burn injuries reconstructed with ovine forestomach matrix (OFM), leading to full recovery and satisfactory cosmetic outcomes.[28]

Case study 5. Paediatric scald burn reconstructed with a synthetic polymeric matrix and dehydrated human amnion/chorion membrane

Courtesy of Paul Glat

An 18-month-old girl presented with first- and second-degree scalds on her left face, ear, neck and shoulder, covering 8% of her body surface. She was immediately treated with a topical antibiotic. On day 2, the shoulder burn was treated with collagenase; the facial and ear burns were covered with synthetic polymeric matrix; and all wounds were covered with a non-adherent dressing. On post-burn day 5, the facial and ear wounds had healed 98%. The neck and shoulder burns were surgically debrided and covered with dehydrated human amnion/chorion membrane. On post-burn day 10, polymetric matrix had been absorbed and the face and ear were fully healed. On post-burn day 22, all burns were fully healed, with near-normal pigmentation.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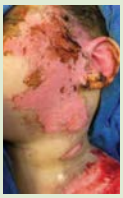
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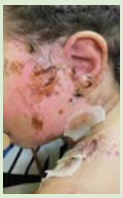
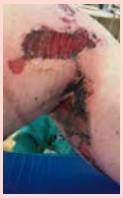

Day 10


Day 22

Case study 6. Second-degree burn reconstructed with a synthetic polymeric matrix

Courtesy of Michael Schurr

A 20-year-old man presented with a non-circumferential second-degree burn on the posterior and anterior lower left leg, caused by a vape pen exploding in his pocket 30 minutes prior to admission. The wound, which was was painful and sloughing, covered 4% of his body surface area. The patient received analgesia, and the wound was irrigated, treated with silver sulfadiazine and non-occlusive sterile dressings. On day 2, the wound was debrided and covered with a synthetic polymeric matrix, followed by gauze and a wrap. After 7 days, the wound was dry and painless and had fully re-epithelialised.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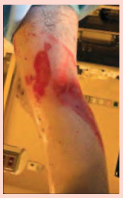
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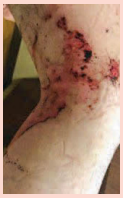
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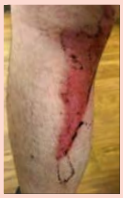
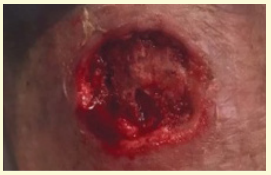

Day 7

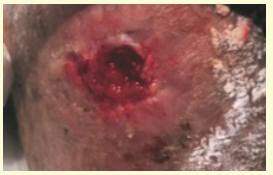
Trials have compared a fish-skin xenograft with standard of care for treatment of partial-thickness burns.[29] In a 2020 phase-two RCT by Lima Júnior et al, the xenograft was associated with significantly fewer days to complete re-epithelialisation and need for significantly fewer dressing changes, as well as lower pain intensity and fewer pain medications required.[30]

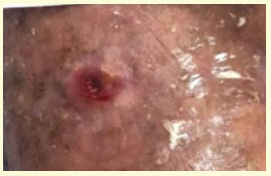
Case study 7. Post-Mohs leg defect reconstructed with a polyhexanide-coated native collagen extracellular matrix and hypothermically stored amniotic membrane

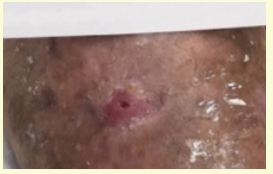
Courtesy of Daniel Kapp

A 95-year-old woman presented with a 10.5 cm^2 surgical wound on her right leg after Mohs surgery to remove a squamous cell carcinoma 1 week earlier. She had a history of venous insufficiency. To control bioburden and support healing, the wound was managed with six applications of a native extracellular matrix (ECM) coated with antimicrobial polyhexanide, followed by one application of a hypothermically stored amniotic membrane (HSAM) as a protective barrier. Complete closure was achieved at 8 weeks.


First ECM plus polyhexanide application


Sixth ECM plus polyhexanide application


HSAM application


Week 8, full closure

In a 2017 review of techniques for burn reconstruction, Glat and Davenport described how CAMPs, specifically amniotic membrane allografts, can be used as an effective treatment for burn injuries being healed by secondary intention, primary closure or with skin grafts, tissue expansion or flaps. Outcomes included more durable grafts, faster healing and, in some cases, avoidance of more invasive procedures.[31]

Craniotomy and craniectomy

The use of dehydrated human amnion chorion membrane (dHACM) allografts with closure of craniotomies and craniectomies has been reported for augmentation of dural repair. Several articles by Eichberg et al have described the use of dHACM allografts in transsphenoidal endoscopic endonasal surgery to augment epithelialisation, facilitate wound healing, impede bacterial growth and prevent cerebrospinal fluid leaks.[32,33] In a 2023 study of seven patients by Endicott et al, dHACM allografts were placed intraoperatively during emergent craniectomies in order to reduce dural adhesion formation and subsequent cranioplasty complications. Negligible adhesions and no complications were found when follow-up closure with an autologous skull cap or implant was performed.[34]

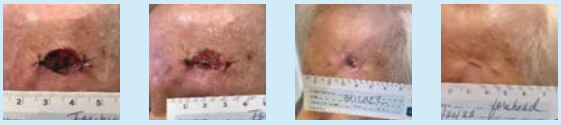
Excision of skin cancers

Numerous articles have reported success using CAMPs for closure of post-excisional wounds due to skin cancers (*Case studies 7–9*).[35–37]

Case study 8. Post-Mohs forehead defect reconstructed with hypothermically stored amniotic membrane[39]

Courtesy of Daniel Kapp and Laura Pfendler

A 92-year-old woman presented with a 2.52 cm^2 post-Mohs left forehead wound defect following removal of a basal-cell carcinoma 8 days previous. She had a history of hypertension, heart murmur and skin cancer. The wound was managed with hypothermically stored amniotic membrane (HSAM) as a protective barrier, in conjunction with partial closure. After 4 weeks of treatment and four applications of HSAM, the wound had reduced in area by 78.6%. Full closure was achieved within 2 months.

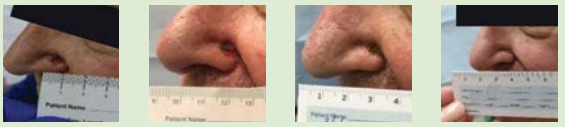


Day 8 | Day 20 | Day 44 | Month 3

Case study 9. Post-Mohs nasal defect reconstructed with hypothermically stored amniotic membrane[39]

Courtesy of Daniel Kapp and Laura Pfendler

A 93-year-old male patient presented with a 1 cm^2 post-Mohs left nasal wound defect after excision of a basal-cell carcinoma 6 days before. He had a history of cardiac disease, hypertension, four coronary artery bypass grafts and COVID-19 pneumonia. The wound was managed with hypothermically stored amniotic membrane as a protective barrier in four applications. Full closure was achieved after 29 days.

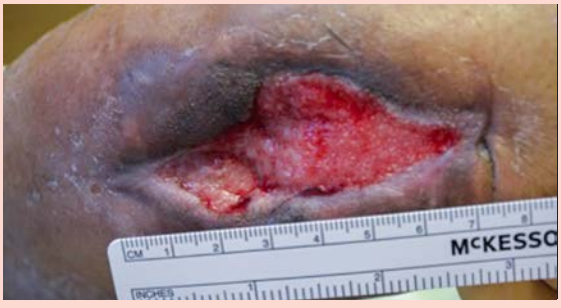


Day 6 | Day 20 | Day 28 | Month 3

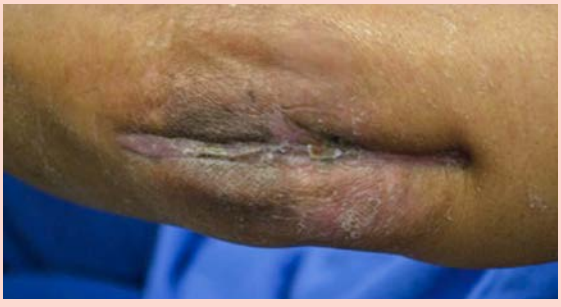
Case study 10. Hard-to-heal surgical elbow wound reconstructed with borate-based bioactive glass fibre[126]

Courtesy of Donald W Buck

A 69-year-old man underwent two operative incision, drainage and debridement procedures for an infected olecranon bursa with osteomyelitis and exposed bone. Over the following months, the resulting wound did not heal as expected. From day 212, the wound was treated with borate-based bioactive glass fibre (BBGF) in seven applications. Within 56 days after starting BBGF, the wound had fully closed.



Presentation



Closure

A 2017 single-centre series of 13 cases by Campagnari et al described a two-stage approach to treating skin malignancies with CAMPs to avoid more invasive procedures. Stage one was removal of the tumour and application of the CAMP with NPWT, and stage two was a STSG for closure. The results were positive, with good functional and aesthetic outcomes.[38]

In a 2024 case series by Kapp and Pfendler, seven patients with post-Mohs excisional wounds were managed with hypothermically stored amniotic membrane (HSAM) plus standard wound care. Four patients had been treated for an average of 86.5+/-32.4 days prior to the first application. The patients received an average of 4.6+/-2.5 applications. All wounds achieved full closure, with an average time to closure of 43.7+/-27.1 days. The publication recommended HSAM as an alternative treatment for post-Mohs excisional wounds and concluded that the results suggest that HSAM may be of most benefit when applied early after surgery.[39]

In a 2013 series of five cases by Simcock and May, ovine forestomach matrix (OFM) was placed under a STSG to cover a scalp incision after tumour removal. The CAMP was applied directly to exposed skull with intact periosteum after surgery. There was 95% graft take and 100% re-epithelialisation after 2 weeks, with only one graft procedure required.[40]

Exposed bone

Several studies have shown CAMPs to be effective over exposed bone (*Case studies 10* and *11*).[41,42] For example, a series of six cases by Bohn and Chaffin reported on the use of OFM over exposed vital structures in soft-tissue defects. Granulation was observed within 1–2 weeks, and complete granulation occurred within 1–6 weeks. In the four cases that required a skin graft, granulation tissue was suitable for skin grafting, with 100% take after 1 week and complete re-epithelialisation in 2–3 weeks.[43]

A 2021 case series by Thornburg et al reported on burn or necrotising fasciitis wounds with exposed tendon and bone treated with a combination of dHACM and decellularised human collagen matrix, anchored with NPWT. Closure was observed after two-to-five applications of CAMPs, leading the

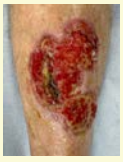
authors to conclude that CAMPs may be an alternative to more-invasive techniques for limb salvage, such as amputation, tissue flap or tissue rearrangement.[44]

A 2022 case study by Ohara et al reported on the use of amniotic membrane allografts on a burn patient with exposed

Case study 11. Hard-to-heal surgical wound with exposed tibial bone reconstructed with a three-layer ovine forestomach matrix[43]

Courtesy of Abigail Chaffin

A male patient presented with a pretibial wound on the anterior lower leg following skin cancer resection. The wound had failed to heal for many months, and there was exposed tibial bone. The wound underwent surgical debridement and burring of the tibial bone with a drill, followed by application of a three-layer ovine forestomach matrix 10×10 cm and negative pressure wound therapy (NPWT). Over the following weeks, the wound fully granulated over the bone. On day 36, the wound was surgically debrided, and a split-thickness skin graft (STSG) was applied. Within 3 weeks, there was full graft take. At day 104, the wound had fully closed, with good soft-tissue coverage over the bone.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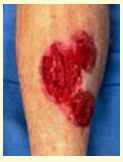
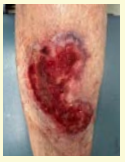
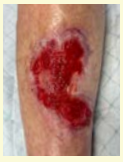
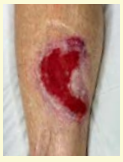

Debrided


NPWT


Day 14


Day 16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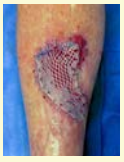
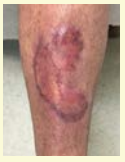
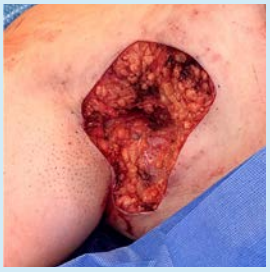

STSG

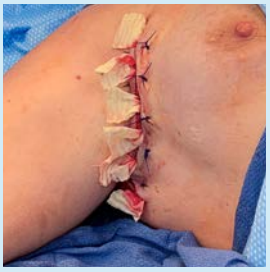

Day 104

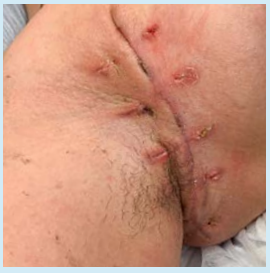
Case study 12. Hidradenitis suppurativa reconstructed with ovine forestomach matrix and flap advancement[59]

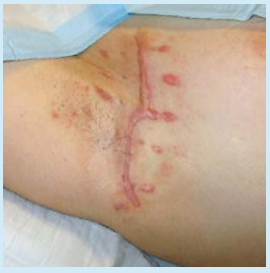
Courtesy of Abigail E Chaffin

A 31-year-old woman presented with hidradenitis suppurativa (present for 5 years) affecting the axilla, with multiple purulent sinus tracts over the inferior half, tunneling laterally to another sinus. The affected area underwent full-thickness excision, leaving a 15×15 cm wound, after which three-layer ovine forestomach matrix was placed on the wound bed to address inflammation of the deep dermal tissues. The wound was closed with advanced local flaps and retention skin sutures, with iodine gauze packing between. The aim was to let the wound drain between the sutures while accomplishing a mostly primary closure. After 3 weeks, the sutures were removed, with no sign of postoperative infection or dehiscence. The wound fully healed in 11 weeks, and at 12 months there were no complications or recurrences.


Excision


Post-procedure

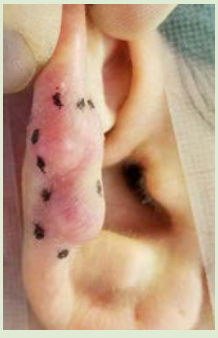

Week 3

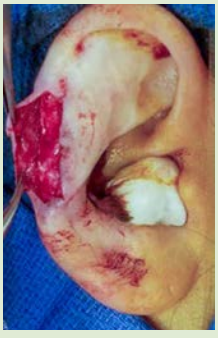

Week 11

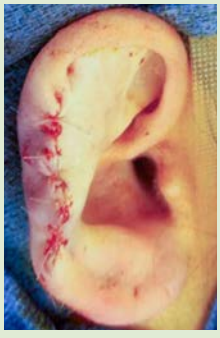
Case study 13. Excised ear keloid reconstructed with cryopreserved placental membrane

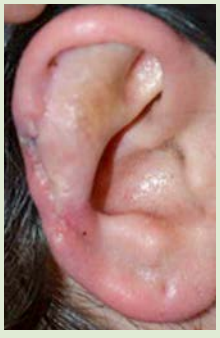
Courtesy of Brian Kiesnowski

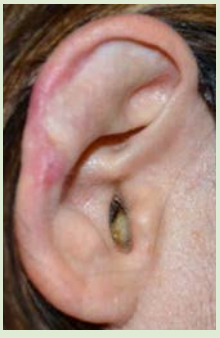
A 35-year-old woman presented with a 3 cm recurrent keloid on the ear. Previous keloids had been excised, followed by full-thickness skin graft and focal radiation treatment, but had continued to recur. Excision of the latest keloid was followed by placement of cryopreserved placental membrane. At 1 year follow-up, there had been no recurrence.


Presentation


Excision


Repair


Month 1


Year 1

tendon, muscle and bone. Treatment consisted of tangential excisional debridement, weekly dressing changes with application of different amniotic membrane allografts, petrolatum gauze with a cellulose gel and NPWT. After 48 days, the patient was discharged with 90% viable STSGs, without the need for myocutaneous flap coverage or an amputation.[45]

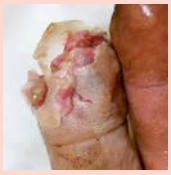
A 2017 literature review by Simman and Hermans examined wounds with exposed tendon and bone treated with esterified hyaluronic acid matrix and concluded that CAMPs can assist in the complete closure of hard-to-heal wounds with exposed structures.[46]

A 2020 case study by Buck demonstrated the benefits of using a borate-based bioactive glass fibre over a surgical wound with exposed bone.

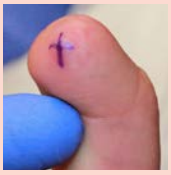
Case study 14. Painful digital neuroma reconstructed with cryopreserved umbilical tissue

Courtesy of Francis Collini

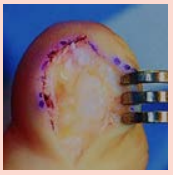
A 45-year-old man presented with an extremely painful ulnar digital nerve neuroma, secondary to a major crush injury to the distal phalanx of the left index finger from a woodchipper, which was treated with complete amputation and flap reconstruction. A trigger point was interfering with work and other daily activities. A fasciocutaneous flap was mobilised, and the ulnar digital nerve neuroma excised. The residual digital nerve was wrapped in cryopreserved umbilical tissue and closed. By week 2, the incision was closed; by week 4, the finger had range-of-motion; and by week 6, the patient was back to work.



Original injury



Presentation



Procedure

Hernia repair

Recent studies on the use of CAMPs for hernia repair have focused on comparison of biologic versus synthetic meshes for ventral hernias.[47–53] Studies by Morrison[52] and Dhanani[51] reported no significant differences in using the two types of mesh. Three studies reported fewer complications with the synthetic mesh,[54–56] and a 2021 RCT by Miserez et al was terminated because the recurrence rate with one biologic mesh had significantly more complications, specifically recurrence.[48] Increased recurrence with biologic mesh was also reported in two 2021 RCTs by Harris et al[47] and Olivarria et al.[57] Three studies recommended synthetic over biologic mesh due to the significantly higher costs associated with the biologic, as well as more complications.[49,50,53]

In a 2021 12-month prospective, single-arm, multi-centre study by De Noto et al, ventral hernias treated with a permanent reinforced tissue matrix had a low rate of hernia recurrence and surgical site occurrences requiring intervention at 12 months, illustrating their potential to improve outcomes in hernia repair.[58]

Consensus statement: Biologic meshes and grafts used for reinforcement of soft tissue in hernia repair are significantly different to synthetic meshes and should be counted under the CAMPs umbrella, even if they have a distinct US regulatory pathway.

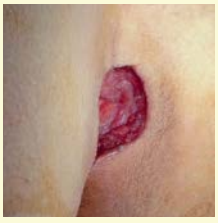
Hidradenitis suppurativa

A 2020 case series by Chaffin and Buckley reported on the application of OFM as part of the surgical reconstruction for Hurley Stage III hidradenitis suppurativa (HS) in six patients (*Case study 12*).[59] The OFM ECM graft was either used as a dermal substitute for staged reconstruction, or as an implant under a fasciocutaneous flap after wide excision of the diseased tissue. Complete closure was achieved in all cases, with granulation supporting a STSG or complete healing of the flap. After 3–12 months of follow-up, all participants had excellent range of motion of the extremity and no reported disease recurrence.

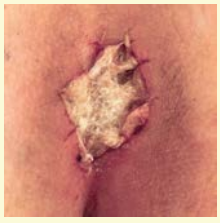
Case study 15. Pilodinal sinus abscess reconstructed with three-dimensional hepatic porcine acellular matrix

Courtesy of Rodney Miller

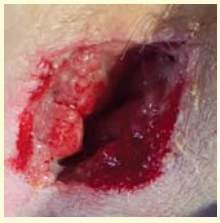
A man presented with a 4x3x2.5 cm surgical wound resulting from the excision of a recurrent pilonidal cyst performed 5 days earlier. A three-dimensional hepatic porcine acellular matrix was placed in the wound and secured with full-thickness sutures. Negative pressure wound therapy (NPWT) (125 mmHg) with a white foam dressing was used for 6 days following matrix placement. By day 6, the matrix had been successfully incorporated into the wound, with visible ingrowth of granulation tissue. The wound fully healed without deformity in 29 days.



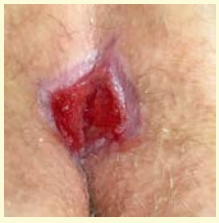
Post-excision



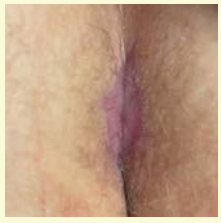
Day 1



Day 8



Day 22

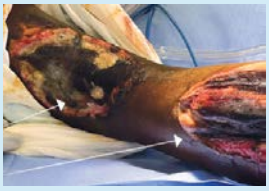


Day 29

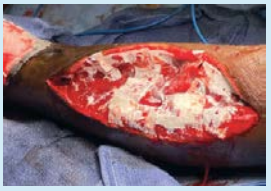
Case study 16. Fasciotomy wounds in arterial disease reconstructed with fresh amniotic membrane

Courtesy of Charlie Cheng

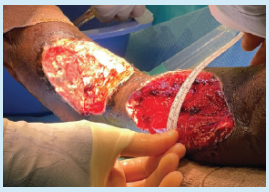
A 60-year-old man presented with a 9×9×0.5 cm arterial wound in the left foot, as well as 20×12×3 cm lateral and 9×4×2 cm medial surgical wounds in the lower left leg following emergency fasciotomy due to reperfusion compartment syndrome 16 days previous. The patient was a smoker and had hypertension, a 1-year history of arterial ulceration and thrombosed stenting. He was at risk for amputation. The three wounds were surgically debrided, washed out and covered with fresh amniotic membrane. After positive results in the first week, fresh amniotic membrane was applied at days 8 and 22. At day 22, there were size reductions in the lateral (19×6×1 cm) and medial (7×2×0.25 cm) wounds.



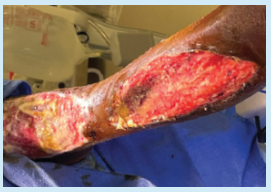
Presentation



Application



Day 8

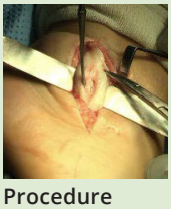


Day 22

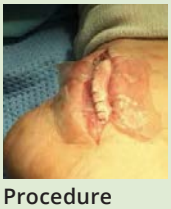
Case study 17. Painful and swollen peroneal tendon reconstructed with cryopreserved placental membrane

Courtesy of Smith+Nephew

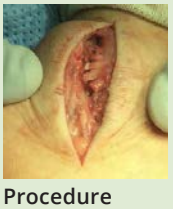
A 43-year-old woman presented with right ankle pain and swelling secondary to peroneus brevis tendonitis and tenosynovitis with a partial longitudinal tear. Conservative care, comprising rest, immobilisation and joint support with ankle foot orthosis, had failed. The right ankle peroneus brevis tendon was wrapped with cryopreserved placental membrane after surgical debridement and repair, followed by closure of the tendon sheath.



Procedure



Procedure



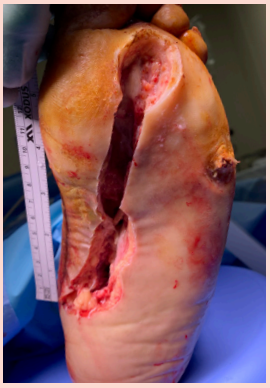
Procedure

In a 2020 discussion of surgical and post-surgical management of HS, Manfredini reported that application of CAMPs prior to a STSG in a two-step procedure may preserve the deep fat tissue, with superior cosmetic results.[60]

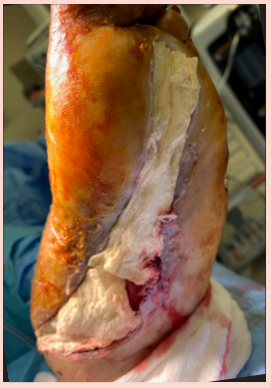
Case study 18. Plantar surgical wound reconstructed with a three-dimensional hepatic porcine acellular collagen matrix[75]

Courtesy of Raymond Abdo and Amy Couch

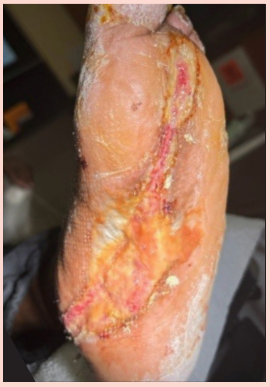
A 47-year-old man underwent drainage and excision of a cellulitic abscess, resulting in a surgical wound extending 17 cm along his left foot. The wound underwent debridement and application of a three-dimensional hepatic porcine acellular collagen matrix (3D-ACM) in three pieces. The wound demonstrated steady progress towards healing and was fully closed by day 68.



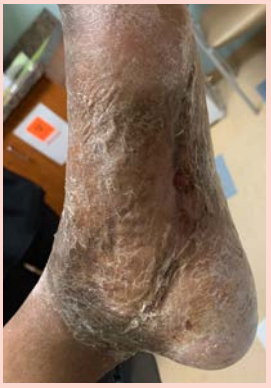
Day 0, presentation



3D-ACM application



Day 25



Day 68, fully closed

Keloid resection

A case study by Gupta et al reported the successful use of viable cryopreserved placental membrane as an adjunct to facial keloid resection (*Case study 13*).[61]

Nerve regeneration

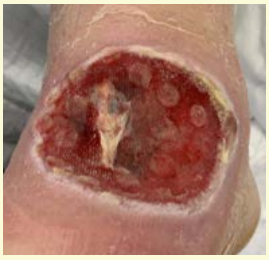
CAMPs can be used to create a conduit for nerve regeneration (*Case study 14*). Animal studies have been promising, with results measured by pin-prick response and sciatic functional index tests.[62–68] A 2015 propensity-matched analysis by Patel et al reported that the use of dHACM as a neurovascular bundle wrap after prostatectomy resulted in enhanced return to continence and potency as compared with a non-graft group.[69]

In a 2017 case series, Rbia et al presented the outcomes of digital nerve gap reconstruction with a collagen nerve conduit and processed nerve allografts, both of which were effective in

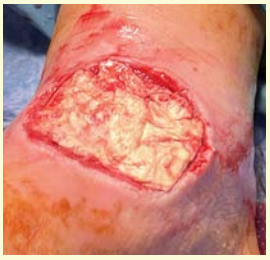
Case study 19. Surgical wound on the ankle reconstructed with three-dimensional hepatic porcine acellular collagen matrix[75]

Courtesy of Raymond Abdo and Amy Couch

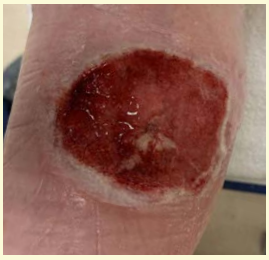
A 60-year-old man underwent incision and drainage of a cellulitic ulceration of the right ankle. After 8 days, the resulting wound exhibited exposed tendon and tunnelling. The wound was treated with a three-dimensional hepatic porcine acellular collagen matrix (3D-ACM). By day 31 after application, the 3D-ACM had fully integrated into the wound bed. Complete wound closure was achieved by day 138 after application.



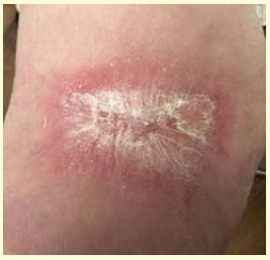
Day 8 after surgery, with exposed tendon



Day 8 after surgery, 3D-ACM application



Day 31 after 3D-ACM application

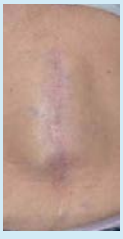


Day 138 after 3D-ACM application, fully closed

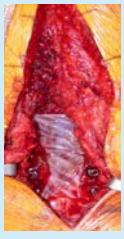
Case study 20. Pseudomeningocele excision reconstructed with cryopreserved umbilical tissue and flap

Courtesy of Smith+Nephew

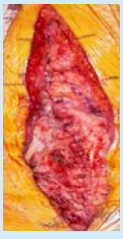
A 57-year-old woman presented with a surgical wound following lumbar laminectomy for removal of pedicle screws and bilateral rods, with excision of pseudomeningocele. She had diabetes, arthritis, gout, hypertension, pulmonary embolism, atrial fibrillation and a history of smoking. Cryopreserved umbilical tissue (CUT) was placed before closure with a bilateral trapezius muscle flap. Negative pressure wound therapy (NPWT) was applied after closure. Full closure was achieved in 1 month.



Pre-op



CUT



Flap

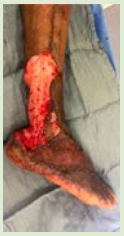
Month 1

Case study 21. Necrotising fasciitis reconstructed with a flap, grafting and small intestinal submucosa extracellular matrix

Courtesy of Smith+Nephew

A 52-year-old man with new-onset type 2 diabetes (blood sugar >600) and significant two-vessel disease, presented 4-days prior to admission with necrotising fasciitis. Over 3 weeks, the wound underwent surgical debridement and negative pressure wound therapy (NPWT), but three surgical services recommended amputation. Due to multivessel disease and no donor vessel, a plan for staged reconstruction was executed. The Achilles tendon was resected, and a small intestinal submucosa extracellular matrix (SIS-ECM) was applied over a sural-based adipofascial flap in preparation a split-thickness skin graft (STSG) to the foot, with a full-thickness skin graft on the donor site. At 23 days after SIS-ECM application, the STSG had healed, there was functional ankle fusion, and the patient was able to ambulate.

Present-ation



SIS-ECM applied

Day 23, STSG

Day 23, ambulating

reconstructing a <2.5 cm digital nerve gap at month 12.[70] In a 2017 retrospective study by Rinker, processed nerve allografts in 28 patients with traumatic digital nerve injuries resulted in recovery in 86% of the repairs.[71]

Consensus statement: Processed nerve allografts, used as conduits to wrap around reconstructed nerves, should be included under the CAMPs umbrella.

Pilonidal sinus

CAMPs can be used to facilitate closure of pilonidal cyst sinuses (*Case study 15*). Three different studies reported on the use of an ECM (either OFM or porcine liver) either as a filling dressing for the sinus or under a reconstructive flap.[72–74] Two of the studies were on paediatric populations with no adverse effects and good wound closure.[72,73]

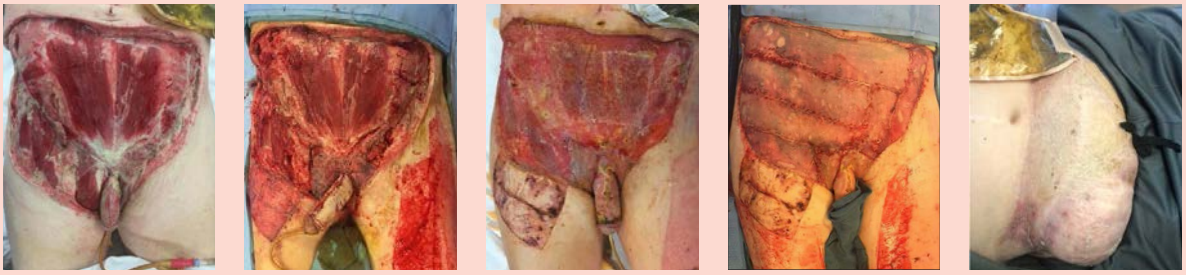
Podiatric surgery

CAMPs have been used to successfully support soft-tissue repair following podiatric surgical procedures (*Case studies 16–19*), particularly those related to the treatment of diabetic foot ulcers (DFUs) and drainage and excision of cellulitic abscesses. A 2024 case series by Abdo and Couch investigated the use of a three-dimensional hepatic porcine acellular collagen matrix (3D-ACM) after surgical treatment of DFUs characterised by depth, tunnelling, undermining or irregular shapes that had been present for at least 4 weeks. Of

Case study 22. Necrotising fasciitis reconstructed with small intestinal submucosa extracellular matrix and skin grafting

Courtesy of Smith+Nephew

A 52-year-old man presented with necrotising fasciitis affecting the lower abdomen, perineum and peri-genital area. He also had a colostomy and type 2 diabetes. Following excision of the affected tissue, reconstruction began with small intestinal submucosa extracellular matrix (SIS-ECM) placed on all exposed muscle tissue. He then had a full-thickness skin graft (FTSG) to the penis and split-thickness skin grafts (STSGs) to the FTSG donor site, perineum and peri-genital area. On day 8, the genital and peri-genital skin grafts were healing, and there was granulation tissue on the muscular abdomen. A lightweight large-pore polypropylene mesh onlay was placed and covered with second application of SIS-ECM. On day 22, the mesh was covered in healthy granulation tissue. After 4 years, there was little visible evidence of the extensive wounds and grafting.

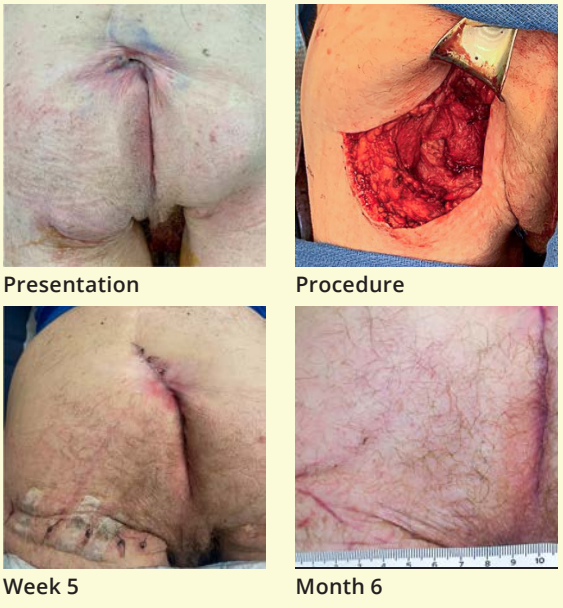


Presentation | Day 1 | Day 8 | Day 22 | Year 4

Case study 23. Excised sacral pressure injury reconstructed with three-layer ovine forestomach matrix and flap advancement

Courtesy of Abigail E Chaffin

A 25-year-old man, paraplegic from a motor vehicle accident, presented with a recurrent stage IV sacral pressure injury and a new stage IV left ischial pressure injury with significant osteomyelitis extending from the ischium to the posterior column of the acetabulum. The sacral pressure injury was excised and the bone resected, after which wound was reconstructed with advancement of left hamstring, gluteus maximus muscle flaps and a complex layered skin closure in the gluteal crease involving three-layer ovine forestomach matrix. The incision healed by week 5, with no complications as of 6 months.



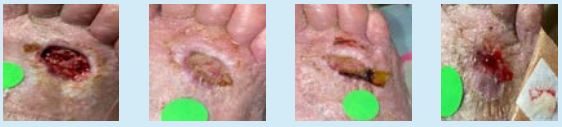
Presentation | Procedure

Week 5 | Month 6

Case study 24. Dorsal crush injury reconstructed with an antimicrobial synthetic polymeric matrix

Courtesy of Damien M Dauphinee

A non-diabetic 98-year-old woman presented with a dorsal crush injury after a sledgehammer fell on her foot 5 weeks before. The wound was covered in black leathery eschar, likely due to anti-coagulant status. Hyperbaric oxygen therapy was contraindicated by the patient's age. The wound underwent sharp and enzymatic (collagenase) debridement of the eschar, followed by three applications of an antimicrobial synthetic polymeric matrix to control bioburden. The wound progressed rapidly to granulation and epithelialisation, reducing in size at days 8 and 15, with full closure by day 28.



Day 0 | Day 8 | Day 15 | Day 28

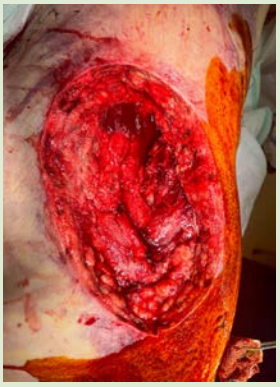
the treated wounds, 62% reached 50% closure by 4 weeks, and 54% were fully closed by 12 weeks. The findings suggest that 3D-ACM provides a protective microenvironment conducive to wound healing, making it a valuable option for managing complex DFUs with deep or tunnelling characteristics.[75]

A 2023 case series by Bosque et al evaluated OFM in the surgical management of 50 challenging lower-extremity soft-tissue defects with exposed structures in patients with multiple comorbidities. One application of OFM was effective in regenerating well-vascularised neodermis, with a mean time to full granulation of 26.0 ± 22.2 days.[41] This data was further validated by a prospective study of 130 lower extremity defects managed with OFM. Despite nearly 50% of the patients in the

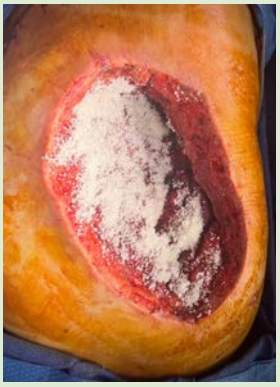
Case study 25. Open hip defect reconstructed with ovine forestomach matrix

Courtesy of Michael Cormican

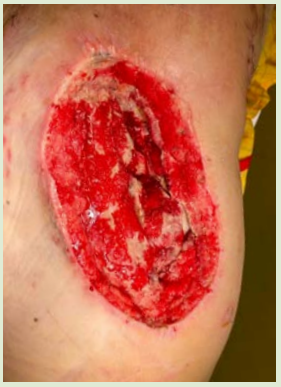
A 36-year-old man presented with an 18×13×20 cm full-thickness right hip wound from a motor vehicle accident 5 days previous. He had been haemodynamically unstable and had undergone exploratory laparotomy with resuscitative endovascular balloon occlusion of the aorta (REBOA), as well as serial sharp debridement and lavage, alongside application of a haemostatic clotting agent, 125 mmHg negative pressure wound therapy (NPWT) and 2000 mg of powdered ovine forestomach matrix (OFM) hydrated with blood in situ. Subsequently, two five-layer 10×20 cm pieces of OFM were quilted together and stapled to the wound, followed by application of a petroleum gauze contact layer and 125 mmHg NPWT. By day 8, the OFM had rehydrated and was integrating well, with formation of robust, vascular granulation tissue. The wound had significantly reduced in area by week 4, 95% epithelialised by week 11 and fully epithelialised by week 13 (no photo). At week 21, the patient was highly satisfied with the scar and able to ambulate. Pain was well controlled throughout, and there were no complications.



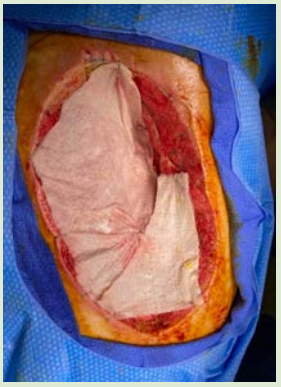
Presentation



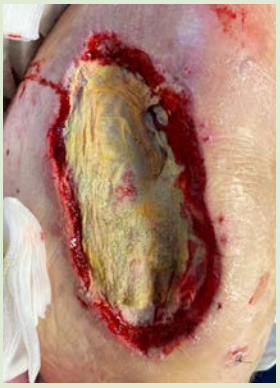
Powdered OFM



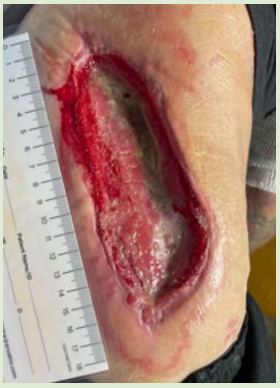
Day 5, after debridement



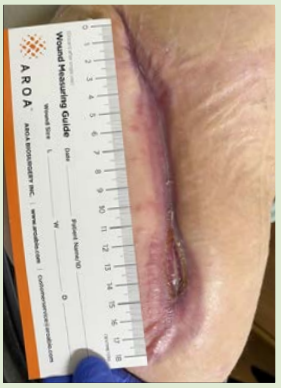
Day 5, layered OFM



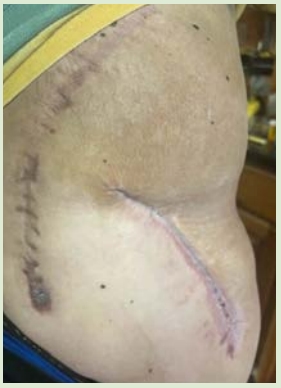
Day 8



Week 4



Week 11



Month 2 after closure

cohort being positive for osteomyelitis, the median time to vascularised tissue coverage or infill of the defect was 30 days, with no documented infections or graft explants.[42]

Pyoderma gangrenosum

Five studies reported that the use of dHACM in conjunction with surgical debridement and immunotherapy resulted in decreased inflammation, pain and metalloproteinase levels, as well as increased cellular proliferation and closure an STSG.[76–80]

Tissue flaps and grafts

CAMPs can be used in combination with tissue flaps and grafts for a multimodal approach to soft-tissue reconstruction in a variety of presentations, including necrotising fasciitis (*Case studies 20–23*). For example, certain CAMPs, including OFM and select amnions, can be placed beneath a tissue flap to augment the repair or support an at-risk flap.[81,82]

Trauma

CAMPs have been used in traumatic wounds with positive outcomes (*Case studies 24* and *25*). A 2023 case series by Cormican et al demonstrated that OFM was able to facilitate the formation of functional, well-vascularised soft tissue in 13 large, complex and contaminated volumetric soft-tissue defects.[83] A 2021 case study by Eudy et al demonstrated a living cellular skin substitute to be a viable alternative treatment option to STSG for full-thickness skin injury in paediatric patients.[84]

Fitting CAMPs in the care plan

CAMPs can be used on a wide variety of acute, hard-to-heal and surgical wounds, with the appropriacy of using CAMPs in specific clinical presentations dependent on the creative judgement of the physician.[85,86] CAMPs can eliminate the need for flaps for select patients, which are often performed to cover structures such as bone, joints, tendons and cartilage that will not support coverage with a skin graft due to lack of vascularity. The use of a CAMP allows growth of tissue over structures that otherwise would not allow skin grafting. Some simply create granulation tissue, but others such as dermal regeneration templates, decellularised matrices and biodegradable temporising matrix create a substance that looks histologically different from granulation tissue and represents a neodermis that is suitable for grafting.[44,87]

Early intervention and the reconstructive ladder

Reports demonstrate numerous important clinical benefits from appropriate intervention with CAMPs early in a patient's care plan, rather than as a salvage technique of last resort (*Box 1*). There is extensive evidence in DFUs and VLUs that early use of CAMPs in conjunction with standard of care supports faster healing, fewer complications and better patient quality of life,[88–93] with consequent economic benefits for providers and patients.[94]

Consensus statement: The significant benefits of earlier use of CAMPs, being proven in the most challenging-to-heal wound types, should apply equally to acute surgical and traumatic wounds, making CAMPs a valuable tool in the surgical armamentarium.

However, in current practice, CAMPs may not be considered an option in the early stages when they might provide the optimal benefit. In soft-tissue reconstruction of acute surgical and traumatic wounds, the early availability of CAMPs depends on where they fit on the reconstructive ladder (*Figure 1*). When a care plan is guided by the reconstructive ladder, treatment begins at the bottom rung with the simplest appropriate method available. Treatment can only be escalated through more complex methods if simpler methods prove inappropriate or ineffective for repairing the defect and restoring tissue function.[88,95]

Consensus statement: The reconstructive ladder for acute surgery for soft-tissue reconstruction should be updated to guide the optimal use of CAMPs. This could include introducing CAMPs application into care plans before more complex procedures, such as tissue transfers and flaps. For example, CAMPs could be an option to facilitate healing in preparation for a skin graft or during the proliferative phase of closure by secondary intention. This could shorten the reconstructive ladder for patients, as well as avoid the need for more invasive and risky procedures. Moreover, CAMPs that can reinforce the structure of soft tissue in surgical sites may have a role at every rung of the reconstructive ladder, including in relation to complex patients in whom flaps and transfers are unavoidable.

Definitively situating CAMPs within the formal care plan will also reassure patients that these advanced treatments are not an option of last resort.[31]

The traditional reconstructive ladder has been critiqued as insufficient for addressing the complex comprehensive needs of patients undergoing soft-tissue reconstruction in acute surgical and traumatic wounds. Alternative models include the plastic surgery compass, in which the ladder of procedural complexity is considered alongside the three other dimensions of personal factors, patient risks and the anatomical problem.[96]

Consensus statement: The use of CAMPs and their incorporation into care plans should not only improve overall clinical and economic outcomes; it could also help stakeholders move the framework for soft-tissue repair in acute and surgical wounds beyond an ordinal ladder and into more patient-centred and multidimensional practices.

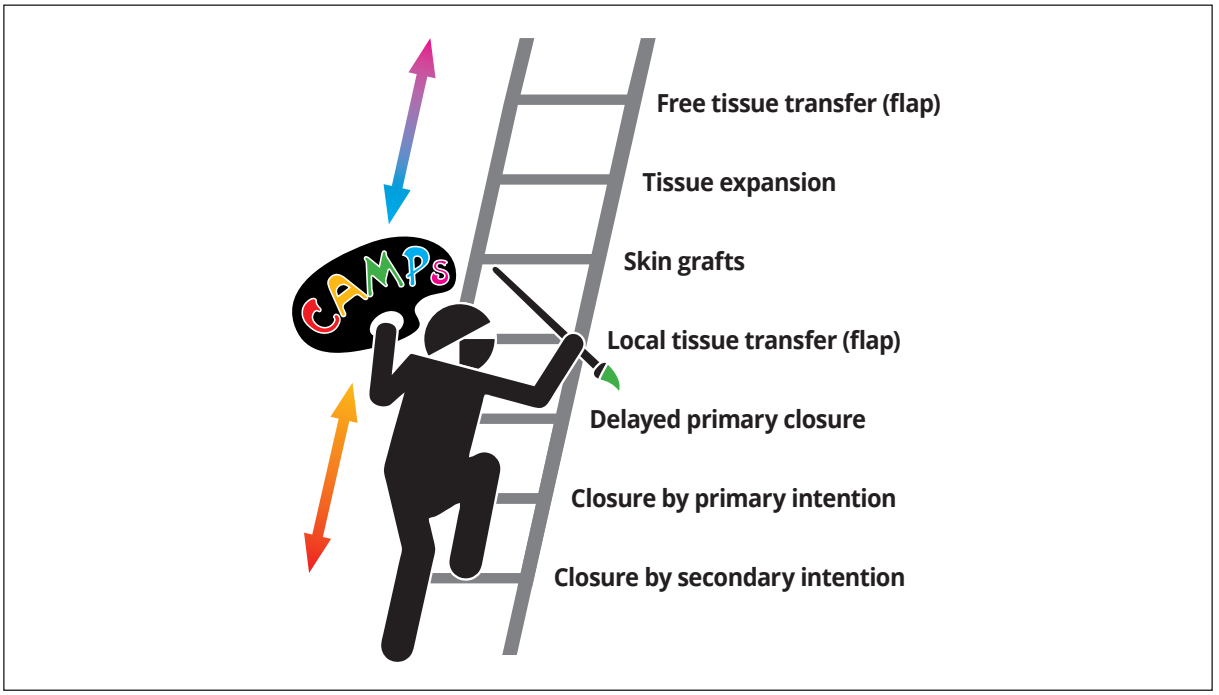
Assessment, preparation and application

CAMPs should always be used as an adjunct to a multifaceted and comprehensive care plan, rather than being considered a replacement for any of the established evidence-based fundamentals of wound care.[6] Moreover, care plans and treatment protocols should be guided by the appropriate frameworks and guidelines for the patient's presentation and the chosen interventions.

Box 1. Potential benefits of early intervention with CAMPs

- Prevent hospitalisation when CAMP can be applied in an outpatient setting[129,130]
- Contain living cells and growth factors known to stimulate wound healing[131,132]
- Support angiogenesis and dermal fibroblast proliferation, reducing time to full wound closure[100]
- Provide scaffolding for tissue ingrowth[133–135]
- Increase tensile or mechanical strength of tissue[134]
- Protect underlying vital structures, such as bone, tendons, ligaments, muscles and organs[43,46]
- Reduce scarring due to fewer myofibroblasts and increased type III collagen[136–139]
- Improve aesthetic outcomes[140]
- Obviate more invasive procedures, such as amputations, flaps or tissue transfers[44]
- Minimise complications and reduce hospital length of stay[141–142]

Figure 1. Use of CAMPs at each step of the reconstructive ladder



The first step in any care plan is a comprehensive patient assessment to identify any potential contraindications or relevant comorbidities. Several potential contraindications must be carefully considered before making a clinical decision to proceed with using a CAMP (*Box 2*). Ongoing smoking or vaping should be considered cautions, as these increase risk of failure, although there may be significant benefits in the use of a CAMP in the treatment of a DFU on a patient who smokes.[97] Comorbidities that may inhibit wound healing should be adequately managed through prehabilitation before proceeding. This comprehensive approach to patient care is imperative for success of any wound intervention but especially for the use of a CAMP. Assessment is also an opportunity to obtain patient consent for CAMPs application.

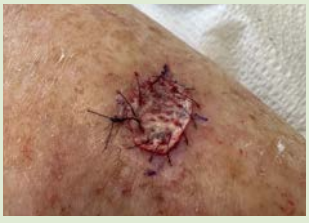
Consensus statement: The principles of proper wound management apply equally to acute and hard-to-heal wounds. For example, underlying aetiologies or contributory comorbidities require best-practice treatment, such as revascularisation for arterial insufficiency, compression therapy for venous insufficiency, offloading for DFUs and pressure redistribution for pressure injuries (PIs). One of the challenges of acute surgery is to address comorbidities prior to the surgical procedure. Likewise, a successful care plan involving CAMPs should also be holistic, aiming to treat the whole patient, incorporate their goals and manage comorbidities.

The next essential step is adequate preparation of the wound bed or surgical site, as described in the TIMERS framework for best-practice wound care (*Box 3*). CAMPs can play a critical role in the repair and regeneration (R) aspect of TIMERS, as well as potentially help modulate inflammation and infection.[98,99]

Consensus statement: An adequately prepared surgical site or wound bed may not require prophylactic antimicrobial dressings in conjunction with the use of CAMPs, and use of cytotoxic products is strongly discouraged except in the presence of invasive pathogens or when the benefits outweigh the risks.

A CAMP should be first applied as early as possible, such as at the time of surgical debridement or flap/tissue reconstruction. For clean surgical wounds, this may mean proper coaptation

Figure 2. CAMP sutured in place with full contract with the underlying tissue



Courtesy of Rose Hamm

Box 2. Potential contraindications for CAMPs

- Infected tissue in the wound bed
- Necrotic tissue in the wound bed
- Allergy to components
- Religious objections to source tissue or other components
- Unmanaged relevant comorbidities (e.g., uncontrolled glucose levels due to diabetes)
- Low chance of adherence to post-applications instructions

(drawing together of separated tissue) and apposition to the underlying surgical bed and surgical fixation of the graft as indicated (*Figure 2*). Further RCTs are needed to confirm optimal time of application for acute surgical wounds. Application of a CAMP should adhere to the manufacturer's product-specific protocols, which should be reviewed prior to application (e.g. hydrating a dehydrated or cryopreserved product).[6]

Consensus statement: Generally, the CAMP should be placed directly on the healthy tissue in the wound. Care should be taken to maintain full contact with the wound surface, because dead space between the two surfaces can lead to accumulation of fluid (seroma or haematoma), which can result in CAMP failure.

CAMPs can be secured with sutures, staples, closure strips or other means, as indicated. The CAMP is generally covered with a secondary bolster dressing, NPWT or compression, which can also help eliminate dead space between the wound bed and the CAMP. The goal of the secondary dressing is to prevent slippage and minimise shear between the surfaces and thereby reduce the risk of product failure and the possible need for reapplication.[6] After application, other components of best practice for the wound diagnosis may need to be provided.

Consensus statement: A complete patient assessment and adequate preparation of the surgical site or wound bed are required prior to the application of a CAMP to any wound.

Monitoring and reapplication

The optimal frequency and number of CAMPs application has not been definitively determined. These are likely to vary from case to case according to the function of the specific product and the needs of the individual patient, as well as the wound's size, aetiology and expected outcome, such as preparation for a skin graft versus complete closure by secondary intention. For example, in a multicentre prospective study by Galiano et al, weekly reapplication on DFUs resulted in 85% of participants healed within 12 weeks.[100] There is variation in reported application rates for CAMPs used in acute trauma and reconstructive surgery.[42,101] Repeated applications are usually performed in an outpatient setting. However, for the majority of commercially available CAMPs, the first application is usually left in place for 7–14 days, depending on the goal of treatment. This is supported by a 2021 retrospective analysis of Medicare patients with lower extremity DFUs treated with CAMPs, in which reapplication occurred every 7–14 days,[102] the principle of which should be transferable to acute surgical and traumatic wounds.

Consensus statement: After application of a CAMP, the patient should be monitored. At every dressing change, the patient must be reassessed to determine their status and wound progression, as well as identify any factors that could affect the healing process. This reassessment allows the care plan to be adjusted accordingly and the CAMP to be reapplied or discontinued as appropriate. Ideally, a patient's progress will be monitored with comparative outcome measures and digital photographs taken at regular intervals. This monitoring data can support clinical decisions for the individual patient, as well as provide surveillance data to study the wider population.

Consensus statement: The multidisciplinary team should receive education regarding post-application care of a CAMP, covering the option of only changing the secondary dressing, the need to take care when removing secondary dressings and the importance of not accidentally removing the CAMP.

Box 3. TIMERS wound care tool[98,99]

T	Tissue – removal of devitalised tissue via debridement
I	Inflammation and infection – control of infection and inflammation through debridement and antimicrobials and cleaning with surfactants
M	Moisture – maintenance of a moist environment conducive to healing
E	Edges – refashioning and debridement to remove callus
R	Repair/regeneration – consideration of advanced therapies such as CAMPs to facilitate closure of hard-to-heal wounds
S	Social and patient-related factors – promotion of patient concordance and satisfaction with treatment with patient education, active listening and motivational interviewing

Adjunct therapies

Use of CAMPs in soft-tissue reconstruction in acute surgical and traumatic wounds could be supported by adjunct therapies, extrapolating from examples established in hard-to-heal wounds:

- NPWT may be used to stabilise the CAMP, reduce the interstitial oedema and prevent shear, following examples in DFUs, scalp necrosis and wounds associated with paediatric disorders,[103–106] although a study by Veale et al illustrated the importance of pre-clinical testing to ensure the selected CAMP does not reduce the negative pressure delivered by NPWT systems.[107]
- Hyperbaric oxygen (HBO_2) therapy can be used in conjunction with CAMPs, following reported treatment for DFUs[108–110] and irradiated skin after tumour removal.[111] In both cases, the benefits of HBO_2 therapy include maintenance of tissue oxygen supply; improvements in neovascularisation and tissue perfusion; reductions in inflammation and oedema; and bacteriostatic/bactericidal effects.[112–116] Recommendations for HBO_2 therapy vary internationally.
- Electrical stimulation can be used with CAMPs, following a case series by Zhou et al showing that, when a high volt pulsed current was placed over a saline-soaked collagen dressing (left in place after the treatment enhanced healing) on full-thickness hard-to-heal wounds of at least 6 weeks' duration, both surface area and volume decreased significantly after 2 weeks of treatment.[117] The effects of electrical stimulation on wound healing include antibacterial actions and galvanotaxis, as well as increased growth factor secretion, proliferation and angiogenesis.[118,119]

Overcoming barriers to implementation of CAMPs

There are several barriers to greater uptake of CAMPs for soft-tissue reconstruction in acute surgical and traumatic wounds, including training, costs and reimbursement.

Training

CAMPs can be applied by healthcare providers who are trained in their selection and application. In practice, this restricts use of CAMPs to surgeons, physicians and their assistants who have the skills to perform surgical debridement, suturing or stapling, which may be needed as part of the application process, alongside other specialist wound-care skills, such as wound bed preparation.

Providers in fields including soft-tissue reconstruction in acute surgical and traumatic wounds can be trained in these skills. This training could follow a model established in a 2-day, immersive, cadaver-based skills course reported by Bowyer et al.[120,121] This standardised model, developed with best practices in instructional design, demonstrated significant improvement in procedural skill performance following direct measurement after training.[120,121] Alternatively, manufacturer representatives may provide guidance on the use of a CAMP in both the office and operating room.

Consensus statement: Providers working in acute surgery should receive specialist training on the science behind CAMPs.

Product selection

There is considerable variation between and within each compositional category of CAMPs (*Table 2*).[6] Different CAMPs vary in their mechanism of action, as well as in the effect they have on cellular activity and healing processes. Placing a CAMP in contact with host tissue may result in the following three activities:

- Extracellular signalling
- Intercellular communication between the cells in the CAMP and the cells in the host tissue
- Extracellular matrix (ECM)-linked or scaffolding activities.[6]

Consensus statement: Understanding how different CAMPs work is critical in the selection of the optimal product for each individual patient.

There is a wide range of CAMPs on the market, with different components and modes of action. Consequently, some CAMPs may be more suitable than others for different diagnoses, presentations and stages of wound healing. For example, there is evidence from murine studies and clinical data by Reed that dermal allografts promote re-epithelialisation, amniotic membrane allografts promote granulation and angiogenesis and dHACM allografts support all stages of wound healing. However, the present understanding of these differences in suitability is limited and represents a gap in understanding.[122]

Consensus statement: The ongoing development of CAMPs would benefit from surveillance data collected through a CAMPs registry, established in the model of cancer registries. It would also be valuable to collect comparative data on how frequently CAMPs are used by different specialties, including how CAMPs-related costs are reimbursed and distributed throughout the healthcare system.

Costs

Evidence suggests that the cost of CAMPs is outweighed by the financial impact of improvements in clinical outcomes brought about by their appropriate use. Cost savings include reductions in healing time, operating-room hours and dressings changes, as well as less-intense labour demands and faster return to function and work.[123] Patients and wider society also benefit economically from use of CAMPs to accelerate wound-healing times and thus functional recovery and return to work, thereby reducing loss of income and productivity.[69] The cost-effectiveness of CAMPs has been demonstrated in several studies on hard-to-heal wounds:

- In a 2021 retrospective analysis by Armstrong et al, use of CAMPs in 900 000 Medicare patients with DFUs resulted in significantly fewer minor amputations, major amputations, emergency department visits and readmissions.[102]
- In a 2022 companion retrospective analysis by Tettelbach et al, use of dHACM in 1 million Medicare patients with DFUs resulted in fewer amputations and lower use of healthcare resources, amounting to a cost saving of $3670 per patient.[124]

Table 2. Categorisation of CAMPs[6]

Category	Subcategory
Cellular	• Autograft (viable) • Allograft (viable or non-viable)
Acellular	• Allograft • Xenograft
Matrix-like	• Natural • Synthetic

- In a similar 2021 study in the UK, use of dHACM in DFUs in secondary care was found to be cost-effective.[125]
- In a 2024 cost-effectiveness analysis, use of CAMPs in 530 220 Medicare patients with VLUs resulted in better clinical outcomes and a cost saving of $1178 per patient.[94]
- A 2020 case series by Buck reported that the application of borate-based bioactive glass fiber (BBGF) advanced wound matrix on hard-to-heal wounds that had not responded to other strategies produced significant cost savings.[126]
- In a 2024 cost-effectiveness comparison by Nherera and Banerjee, the total cost of caring for a patient with a DFU was lower when using five of the six CAMPs than standard of care alone. The authors cautioned that there was no head-to-head evidence comparing the different CAMPs, and the cost analysis would need to be updated when more direct evidence became available.[123]

Table 3. CAMPs application procedure codes[7]

Code	Details
15271	Application of skin substitute graft to trunk, arms, legs, total wound surface area up to 100 cm^2; first 25 cm^2 or less wound surface area
15272	Application of skin substitute graft to trunk, arms, legs, total wound surface area up to 100 cm^2; each additional 25 cm^2 wound surface area, or part thereof*
15273	Application of skin substitute graft to trunk, arms, legs, total wound surface area greater than or equal to 100 cm^2; first 100 cm^2 wound surface area, or 1% of body area of infants and children
15274	Application of skin substitute graft to trunk, arms, legs, total wound surface area greater than or equal to 100 cm^2; each additional 100 cm^2 wound surface area or part thereof, or each additional 1% of body area of infants and children, or part thereof*
15275	Application of skin substitute graft to face, scalp, eyelids, mouth, neck, ears, orbits, genitalia, hands, feet and/or multiple digits, total wound surface area up to 100 cm^2; first 25 cm^2 or less wound surface area
15276	Application of skin substitute graft to face, scalp, eyelids, mouth, neck, ears, orbits, genitalia, hands, feet, and/or multiple digits, total wound surface area up to 100 cm^2; each additional 25 cm^2 wound surface area, or part thereof*
15277	Application of skin substitute graft to face, scalp, eyelids, mouth, neck, ears, orbits, genitalia, hands, feet, and/or multiple digits, total wound surface area greater than or equal to 100 cm^2; first 100 cm^2 wound surface area, or 1% of body area of infants and children
15278	Application of skin substitute graft to face, scalp, eyelids, mouth, neck, ears, orbits, genitalia, hands, feet, and/or multiple digits, total wound surface area greater than or equal to 100 cm^2; each additional 100 cm^2 wound surface area or part thereof, or each additional 1% of body area of infants and children or part thereof*
15777	Implantation of an acellular dermal matrix

*List separately in addition to code for primary procedure

Consensus statement: The economic benefits of appropriate early use of CAMPs in soft-tissue repair in acute surgical and traumatic wounds may outweigh the product costs and deserve ongoing tracking studies.

Reimbursement and coding

In the US, CAMPs are reimbursed via a coding system, explained in detail by Schaum in 2015[127] and 2019.[128] There are application procedure codes for the specific application undertaken (*Table 3*). The CAMP must be applied to a wound of an allowable diagnosis, and these application procedure codes can only be used with CAMPs that have been fixated with the physician's choice of fixation.[127,128,7] There are separate procedure codes for low-cost CAMPs. Code 15777 is for implanted CAMPs, while the others are for topical application.

Consensus statement: Reimbursement practices should be confirmed with each patient's insurance and their local Medicare administrative contractor (MAC).

The US system of reimbursement for CAMPs varies between settings, leading to a complex multitude of pathways, including the healthcare common procedure coding system (HCPCS), diagnosis-related group (DRG) payments, the hospital outpatient prospective payment system (OPPS) and ambulatory surgical center (ASC) payments. When a CAMP is used on a hard-to-heal wound, the cost is often reimbursed directly, based on an application procedure code and an HCPCS code for the specific CAMP. However, when a CAMP is used in an acute surgical or traumatic wound, the cost is not reimbursed directly. Instead, the CAMP forms part of a treatment bundle that limits how much payment a hospital can receive for the treatment of various different clinical indications, and the cost is paid out of the DRG payment.

Consensus statement: In cases where pre-approval of the CAMP is required prior to application, it is mandatory that support personnel understand the approval process, know the checklist system of requirements for approval and coverage, and can convey the necessity of pre-approval to the patient. Even if prior authorisation and predetermination are approved, all checklist items on a payor list should be included in the clinical notes to avoid designation as medically unnecessary and to minimise denials of coverage at the time of payment.

Conclusions

A review of recent evidence shows that CAMPs have not only become established in best practice for hard-to-heal wounds, they are also increasingly being used across a range of surgical specialties, with positive clinical and economic outcomes. This suggests that CAMPs should play a prominent role in soft-tissue reconstruction in acute surgical and traumatic wounds.

Moreover, evidence suggests that CAMPs should be deployed relatively early in the wound-healing process, rather than only as a fallback after other treatments have failed. Early use can improve healing times, patient wellbeing and aesthetic outcomes, as well as minimise healthcare expenditure. As such, early use of CAMPs should be recognised as a best practice in soft-tissue reconstruction in acute surgical and traumatic wounds. Updating the reconstructive ladder to incorporate CAMPs at early stages, where they will be most effective, is essential.[88,95]

Wider and earlier use of CAMPs in soft-tissue reconstruction in acute surgical and traumatic wounds will require developing best practice in assessment, preparation and application, as well as monitoring and reapplication. More data is required on the role of adjunct therapies and the comparative impact of different CAMPs in particular presentations. This information could be gathered through a combination of case studies, RCTs and evaluation of extensive surveillance data.

Consensus statement: The term 'CAMPs' should be used consistently among all stakeholders in all specialties. Earlier application of CAMPs in the wound care plan should be considered to reduce healing times, pain and scarring, as well as minimise dressing changes, enhance functional recovery and provide longer-term cost savings for individual patients and the medical economy. Likewise, the use of CAMPs should be accompanied by extensive surveillance to collect data, study their impact and optimise their use.

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