JWC International Consensus Document



LIMB PRESERVATION

WITH CELLULAR, ACELLULAR AND MATRIX-LIKE PRODUCTS (CAMPS)

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FOREWORD

Limb preservation represents a commitment to restoring function, independence and quality of life for patients at risk of amputation. As the chair of this consensus panel, I am pleased to present this document to the medical community. It was developed to advance the science and practice of limb preservation through the informed application of cellular, acellular and matrix-like products (CAMPs).

This consensus document is the result of a collaborative, interdisciplinary effort among key opinion leaders, aimed at meeting the increasing demand for updated, practical and evidence-informed guidance on the use of CAMPs. The discussions were rooted in clinical experience and bolstered by emerging data, all while maintaining a shared understanding of the complexities inherent in limb preservation. Successfully preserving a threatened limb requires more than selecting the right CAMP; it necessitates thorough patient assessment, interdisciplinary collaboration and a commitment to ongoing reassessment and optimisation.

The document should serve as both a roadmap and a practical resource. It provides actionable recommendations, consensus statements and illustrative case studies that show how CAMPs can be effectively integrated into patient-centred treatment strategies. The document is designed to support all members of the wound-care team, from physicians and nurse practitioners to physical therapists and social workers, helping them make informed decisions that align with both clinical and patient goals. Finally, this document is envisioned as a living resource that will continue to evolve as new evidence becomes available and our collective understanding evolves. Our shared goal is to reduce the burden of limb loss and improve the lives of the patients we serve. The panel would like to thank readers and colleagues for their commitment to this vital work. **JWC**

Windy Cole, Panel Chair

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LIMB PRESERVATION WITH CELLULAR, ACELLULAR AND MATRIX-LIKE PRODUCTS (CAMPS)

In February 2025, an expert panel of 10 key opinion leaders from the US convened in Florida to develop practical, evidence-informed guidance on defining the indications and synergistic use of cellular, acellular and matrix-like products (CAMPs) in limb preservation.

CAMPs encompass a broad category of biomaterials, synthetic materials or biosynthetic matrices, designed to support tissue repair or regeneration through various mechanisms of action.[1] Given the breadth of CAMPs available, they can be organised into a progressively specific taxonomic classification based on cell status, graft source, tissue of origin and graft content (*Figure 1*).

Limb preservation is an interdisciplinary field of medicine focused on preventing and treating conditions leading to lower-limb loss, including healing wounds, controlling infection, optimising circulation and restoring biomechanical function. Beyond saving the limb itself, the discipline seeks to improve the patient's quality of life, maintain their independence and reduce the morbidity and mortality associated with major amputations.

Executive summary

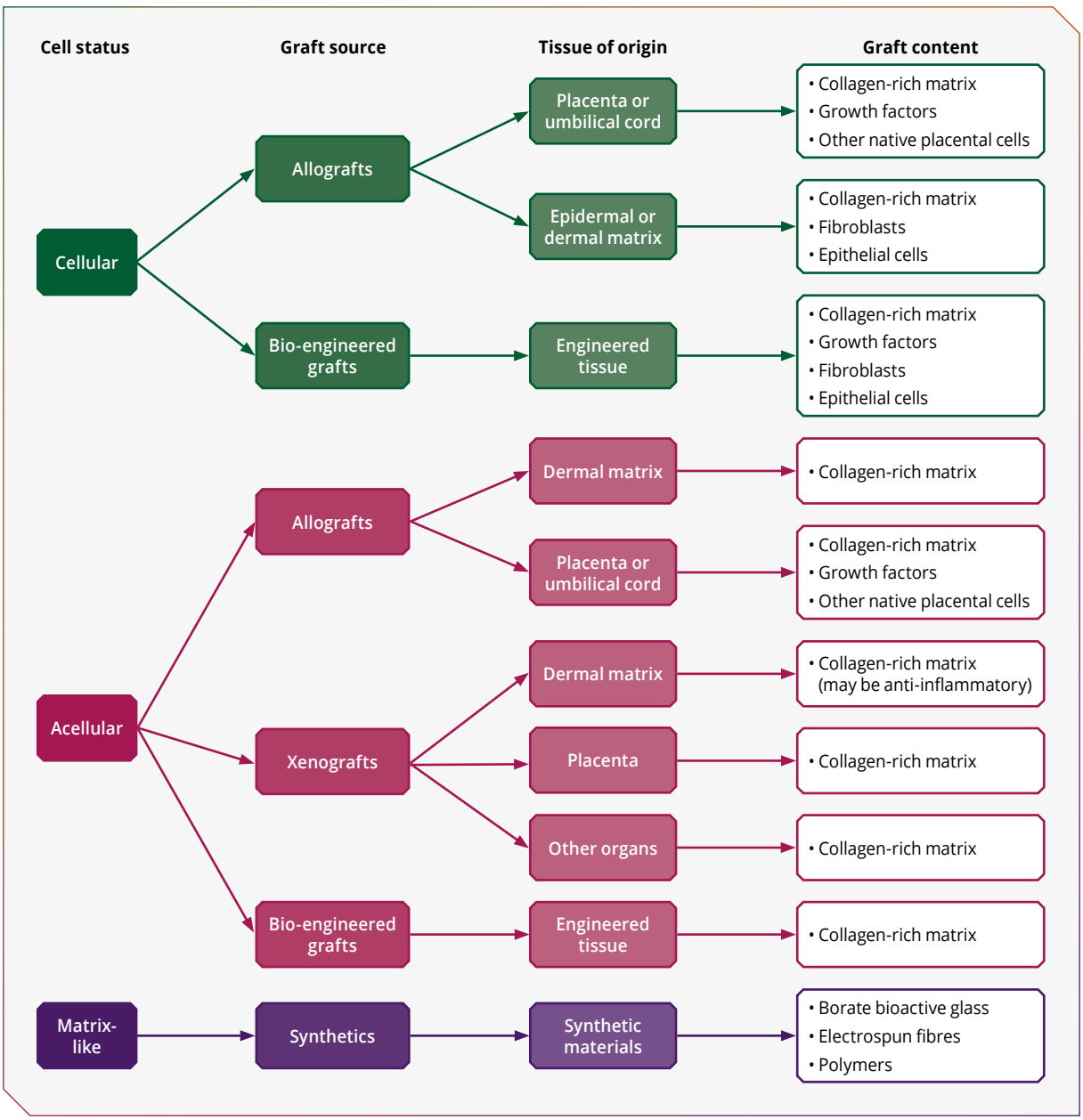
- Limb preservation aims to prevent amputation, improve quality of life and reduce associated morbidity through an interdisciplinary, multimodal treatment approach.
- CAMPs are biological, synthetic and biosynthetic materials, used as adjunctive therapies to facilitate tissue repair and regeneration, thus accelerating healing and reducing recurrence.
- Limb preservation and CAMPs use must be based on a comprehensive, patient-centred assessment to determine whether preservation is feasible and to identify modifiable risk factors that can be optimised prior to CAMP use.
- Patient history should cover comorbidities, medication use and patient/psychosocial factors, as well as wound-specific history.
- Physical examination should encompass vascular, neurological, musculoskeletal, dermatological and wound assessments.
- Diagnostic testing may include standard laboratory tests, wound cultures, wound biopsy and imaging technologies, including novel light imaging where available.
- CAMPs-specific assessment considerations include allergy to specific CAMP components and cultural or religious objections to use of specific CAMPs.
- Use of CAMPs should be integrating within a holistic framework of stabilisation, foundational wound interventions and advanced therapies.
- Limb preservation requires interdisciplinary collaboration, with regular engagement among the care team to ensure timely referral, comprehensive optimisation and integrated treatment.
- Education is essential for patients to understand their treatment options, risks and responsibilities; establish concordance; and participate meaningfully in their care.
- CAMPs have the potential to accelerate wound closure, reduce recurrence and improve patient function and quality of life.
- Early CAMPs use can help speed healing, minimise infection and avoid amputation.

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The use of CAMPs in limb preservation is supported by several, generally product-specific, randomised controlled trials. A product-agnostic systematic review and meta-analysis of various treatments of diabetic foot ulcers (DFUs) reported CAMP use was associated with the best wound-healing probability, faster 12- and 16-week healing rates and a lower risk of ulcer recurrence compared with wounds treated with standard of care alone.[2]

This consensus document offers recommendations to help healthcare providers optimise outcomes when using CAMPs in limb preservation. These recommendations cover how to assess whether a patient is a candidate for limb preservation, as well as how to optimise candidates for CAMP use to help ensure a successful outcome. Recommendations have been referenced to supporting literature where possible, while consensus statements are based on the panel's expert opinion. The recommendations made by the panel are intended for providers and members of interdisciplinary wound-care teams, including all advanced practitioners involved in the care of patients at risk of amputation (physicians of all specialties, nurse practitioners, physician assistants, physical therapists and occupational therapists). Case studies are included to demonstrate how the recommendations can be implemented to facilitate limb preservation.

Figure 1. Classification of CAMPs



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ASSESSMENT

Patients presenting with a leg or foot wound should undergo an initial assessment to determine whether the limb is at risk of amputation and, if so, whether amputation can feasibly be avoided. This assessment should be thorough, comprehensive and patient-centred, covering patient history, a physical examination and diagnostic tests. Assessment can be guided by a standardised checklist of factors that may impair wound healing (*Appendix 1*).

The result of the assessment will inform decisions on whether limb preservation is feasible and if the benefits of attempted preservation outweigh the risks. If preservation is possible, assessment will form the foundation for treatment decisions by identifying modifiable risk factors that can be addressed to stabilise the patient and optimise wound healing, both of which are vital for limb preservation. Treatment should be accompanied by an ongoing process of regular re-assessment to determine progress and inform necessary adjustments to care. To maximise patient engagement, the assessment process should be perceived as open and non-judgemental.

Consensus statement: Lower-limb wounds should be assessed for barriers to healing to determine the necessity and feasibility of limb preservation.

Patient history

Consensus statement: Limb-preservation assessment should capture the patient's relevant history of comorbidities and medication use, as well as holistic patient factors and the history of the presenting wound.

Medical history

Medical history should emphasise comorbidities known to be associated with delayed wound healing, including diabetes, cardiovascular disease, anaemia and obesity.[3–7]

Diabetes is a known key contributor to delayed wound healing due to the detrimental effects of hyperglycaemia on cellular functions necessary for healing.[4] Complications associated with diabetes, notably peripheral neuropathy and its associated loss of protective sensation, contribute to wound formation. Diabetes may also impede wound healing due to alterations in skin integrity and development of muscle–tendon imbalance or musculoskeletal deformities that can result in areas of excessive pressure.[3,8–10]

Cardiovascular disease, including peripheral arterial disease (PAD) and venous insufficiency, results in impaired delivery of oxygen and nutrients and removal of fluid and waste from the wound.[4] PAD is a key contributor to delayed wound healing. Risk factors for the development of PAD include diabetes, coronary artery disease, cerebrovascular disease, hypertension, hyperlipidaemia and chronic kidney disease.[5,6] The classic symptom of intermittent claudication (pain or cramping in the calf muscles) may not be present in those with concomitant peripheral neuropathy, but patients may relate a history of weak knees or leg weakness during walking that is relieved by rest.

Similar to cardiovascular disease, anaemia has been identified as a significant risk factor for delayed healing due to reduced oxygen delivery to the wound site.[11,12] Anaemia is highly prevalent in patients with diabetes and a DFU.[11,13,14] The presence of anaemia in these patients is often due to diabetes and other comorbidities associated with diabetes, such as nephropathy, retinopathy, neuropathy, chronic kidney disease, cardiovascular disease and diabetic foot infection (or as an adverse effect of some antibiotics).[11,13,14]

Obesity negatively affects wound healing due to the avascularity of adipose tissue and its detrimental effects on the cellular function necessary for healing, as well as potential limited mobility and difficulty repositioning for effective wound offloading.[3,4]

Consideration should be given to autoimmune diseases, such as rheumatoid arthritis and systemic lupus erythematosus, as these conditions and their modulating treatments are also associated with a reduced capacity for wound healing.[3,4]

Cancer, as well as the side-effects of chemotherapy, especially peripheral neuropathy, can also impair wound healing.[15]

Medication history

A thorough medication review should assess for therapies known to impair healing. Non-steroidal anti-inflammatory drugs, corticosteroids and immunosuppressive therapies have been associated with a negative impact on wound healing through the suppression of angiogenesis and epithelialisation.[3] In patients with current or previous infections, the antibiotics prescribed should be noted to help determine treatment of future infections and risks of bacterial resistance.

Patient and psychosocial factors

A holistic assessment should explore patient and psychosocial factors that can impede wound healing, especially modifiable factors can be addressed.

This includes use of alcohol, tobacco/nicotine and illicit drugs.[3,16] Tobacco/nicotine use results in vasoconstriction, peripheral hypoxia and immune system suppression and is a primary contributing factor to the development of PAD, all of which can result in delayed wound healing.[3,4] Illicit drug use use can also affect the viability of a limb, and intra-arterial

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and parenteral drug use has been associated with limb loss.[17,18]

The patient's general wellbeing, including their mobility level, functional limitations and ability to use ambulation assistive devices, is essential for understanding their ability to follow recommendations for any required weight-bearing restrictions. This should cover the wheelchair accessibility of their living and work environments. Knowledge of the patient's wider support system, such as the availability of a partner, family members or friends, also helps ensure the patient has transport for required medical appointments, help facilitating adherence to necessary wound-care instructions and support with activities of daily living, especially if mobility restrictions are imposed for wound healing. Employment status is crucial, as the presence of a wound could have a significant impact on work performance for patients, most notably related to the use of sick leave and reduced earning capacity.[19,20] Patients who are employed may also need medical justification for reduced or 'light' work duty, use of offloading devices or modifications to footwear requirements.[19]

Psychological stress and negative emotional states, including depression, have also been shown to have adverse effects on wound healing, related to increased levels of proinflammatory cytokines and chemokines.[4,21,22] Empathetic behaviour from the treatment provider has been shown to improve patient's mental health and increase adherence to treatment plans. Patients with depression should be referred for evaluation and treatment by a mental health professional.

Assessing a patient's baseline nutritional status is crucial for identifying areas needing improvement to support effective wound healing. Patients with chronic wounds should consume a minimum of 30–35 kcal/kg of energy per day, along with 1.25–1.5 g/kg of protein per day.[23] These level may need to be increased for individuals with high exudate to compensate for ongoing nutrition loss. A comprehensive nutritional assessment should include evaluation of the patient's current dietary intake, ability to eat independently, level of physical activity and emotional relationship with food. It should cover any factors that may hinder adequate nutrition, including access to food, dietary restrictions or medication-related dietary limitations, such as fruits (particularly grapefruit), dairy, alcohol and foods containing vitamin K or tyramine.[23] Patient education on appropriate nutrition, including the importance of adequate caloric and protein intake as well as vitamin and mineral supplementation, is essential for wound healing and overall health.

Wound-specific history

The patient should be asked about the length of time they have known the wound to be present, as well as when they first sought medical care for treatment of the wound. Likewise, they should be asked about any factors that led to the wound's development, alongside any therapies used in previous attempts to heal the wound.

Physical examination

Consensus statement: Patients at risk of lower-limb loss should undergo a standardised physical examination ofthe wound, as well as vascular, neurological, musculoskeletal and dermatological factors that can impede healing.

Vascular assessment

A clinical vascular assessment is a key component of limb preservation, as adequate perfusion is necessary for wound healing. The vascular examination begins with visual assessment and pulse palpation. During the visual assessment, clinicians should consider potential indications of PAD, which include:

- Odour of cigarettes and tar staining of the fingers or nails from smoking
- Surgical scars consistent with previous vascular procedures on the neck, chest, abdomen and lower extremities
- Scars from previously healed wounds
- Atrophic skin and lack of digital hair growth
- Amputated limbs or digits.[24]

Palpation and auscultation of the major arterial supply to the leg from proximal to distal, including the femoral, popliteal, posterior tibial and dorsalis pedis arteries, are recommended. Pulse palpation of the lower extremity can be noted as being present or absent, or graded on a 0–4 scale as absent (0), diminished (1), normal (2) increased intensity (3) or bounding (4).[24] Although a palpable pulse is not a sensitive method of ruling out the presence of PAD, the absence of palpable pulses has a high specificity for PAD.[25] Presence of an audible femoral bruit (vascular sound) and absence of palpable pedal pulses are also predictive for PAD.[24] Assessments of lower-limb temperature and capillary refill time are not reliable indicators for PAD.[26]

Use of an audible 8 MHz vascular Doppler is a simple examination that can provide valuable clinical information. The handheld probe is placed over the artery pointed in the direction of blood flow and held at an approximately 60° angle to the skin; adjustments can then be made to hear the clearest sound while avoiding the use of excessive pressure to prevent inadvertent manual occlusion of the artery.[24] Guidelines on the management of PAD in patients with diabetes and a foot wound recommend that an ankle–brachial index (ABI) and a toe–brachial index (TBI) with waveforms be obtained as the first-line diagnostic.[27] An ABI measures the ratio of the systolic blood pressure of the posterior tibial and dorsalis pedis artery and the systolic blood pressure of the brachial artery, which should be equivalent or equal to 1, with a normal range of 1.0–1.3.[24] A TBI measures the ratio of the systolic blood pressure of the digital arteries and the systolic blood pressure of the brachial artery, with normal ranges between >0.6 and >0.75.[28] An ABI or TBI outside the normal range indicate potential vascular issues. Audible or graphic waveforms obtained during ABI and TBI testing are classified as triphasic, biphasic or monophasic.[29] A triphasic signal or waveform consists of three components signifying forward blood flow during systole, a

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transient reversal of blood flow in early diastole and forward blood flow in late diastole. Monophasic signal/waveforms signify vessel abnormalities due to calcification and/or stenosis.[29] Caution should be taken when interpreting an ABI result, as it could be falsely elevated or falsely normal in a patient with PAD and calcified blood vessels, which is often seen in patients who have diabetes. Elevated systolic pressures, non-compressible arteries and monophasic waveforms on ABI results are indicative of calcified blood vessels. The results of a TBI are less likely to be affected by vessel calcification.

If a TBI cannot be obtained due to presence of tissue damage or absence of digits, perfusion status can be evaluated via transcutaneous oxygen pressure measurement (TCOM) or skin perfusion pressure (SPP).[27] TCOM and SPP are not diagnostically definitive but can be useful for evaluating healing prognosis. TCOM measures capillary oxygen tension through local vasodilation and oxygen diffusion to the skin surface. SPP measures pressure obtained by a laser Doppler placed on the foot and/or toe while systolic blood pressure is being measured at the ankle and toe. An adequate healing range for TCOM/SPP is 25–50 mmHg.[30,31]

The assessment of a patient's vascular status should not be based on one vascular indicator alone, especially in patients with a hard-to-heal wound, diabetes or current/former tobacco use. Concern for vascular compromise should be evaluated using a variety of modalities. When there is concern for vascular impaired perfusion, patients should be referred to a vascular specialist for further evaluation and possible intervention. Vascular care should follow the Global Vascular Guidelines, which recommend that all patients with suspected chronic limb-threatening ischemia (CLTI), defined as the presence of PAD with tissue loss or gangrene, should be referred to a vascular specialist, where an invasive diagnostic can confirm the presence of arterial occlusive disease and direct treatment options to improve perfusion.[32]

Neurological assessment

Neurological assessment of the patient should focus on the presence or absence of peripheral neuropathy (especially in patients with diabetes) and loss of protective sensation (LOPS). While history alone can be diagnostic for peripheral neuropathy, LOPS is a more severe form of neuropathy that can be evaluated by examination. Readily available, point-of-care methods that can be used to assess for the presence of LOPS in peripheral neuropathy include 10 g Semmes-Weinstein monofilament (SWMF) testing, vibratory testing using a 128 Hz tuning fork and the Ipswich Touch Test (ITT).[33–35]

Loss of vibratory sensation has a high sensitivity and specificity for detecting the presence of peripheral neuropathy.[35] A systematic review and meta-analysis of the ITT, performed by lightly touching or resting the tip of the index finger on the dorsum of the hallux and the tips of the first, third and fifth toes, found that the test was a suitable alternative to SWMF in detecting peripheral neuropathy. However, it is recommended that clinicians use a combination of these tests to confirm the presence of peripheral neuropathy.[34]

Musculoskeletal assessment

The musculoskeletal assessment should evaluate gait; the strength of leg muscles in the anterior, posterior, lateral and medial quadrants; and the presence of foot and ankle deformities that may contribute to delayed wound healing caused by application of abnormal pressure to the skin and soft tissue. Proximal abnormalities and/or altered muscle strength due to medical conditions, such as cerebral palsy, spina bifidia or stroke, can lead to flexible or rigid deformities of the leg and foot, including ankle equinus contracture, equinovarus, hammertoe, clawtoe and limited joint mobility.[36] These foot deformities may cause excessive pressure, osseous prominences and tissue breakdown, contributing to the development of wounds[8,10,37,38]

For example, Charcot neuroarthropathy is a syndrome that can also occur in any patient who has peripheral neuropathy.[39] Untreated Charcot neuroarthropathy in the active phase can result in the development of the classic 'rockerbottom' deformity in which the medial longitudinal arch of the foot collapses, resulting in an osseous prominence on the plantar aspect of the midfoot.[40,41] These osseous prominences are caused by increased plantar pressure during weightbearing which, if not properly accommodated in custom orthoses, can result in foot ulcers and further complications, such as osteomyelitis and lower-limb amputation.

Foot and ankle deformities are also linked with diabetes (with or without neuropathy) and associated intrinsic foot musculature weakening, plantar-fascia thickening, fat-pad atrophy and reduced tendon elasticity.[8,9] In many cases, foot deformities are bilateral, as the effects of diabetes are systemic, and peripheral neuropathy is typically symmetrical. This means the contralateral foot (from the ulcer) should be carefully examined for signs of pre-ulceration, especially in the same location as the ulcer.

Dermatological assessment

The dermatological assessment should begin with an inspection of the overall quality of the skin, noting atrophy, xerosis, discoloration, blisters, induration, inflammation and/or maceration.[10] Corns and calluses are signs of excessive direct or shearing pressures on the skin. Calluses that contain dark 'pepper spots' are particularly concerning, as they are a sign of haeme deposits from pressure excessive enough to cause bleeding in the callus plaque.

The interdigital skin and nails should be evaluated for the presence of fungal infections, which are common in people with diabetes and may be asymptomatic. Interdigital tinea pedis reduces skin integrity and can lead to a portal of entry for bacterial infections. Onychomycosis can lead to thickened toenails which may receive excessive pressure in the shoe from the upper toe box, leading to subungual ulcerations.

The periwound area should be assessed to determine its suitability for some types of CAMPs. Dry skin, which can be prone to breakdown, is a prominent finding in patients who have diabetes. Skin that is prone to breakdown, thin and/or friable may not be suitable for a CAMP that needs to be anchored to the periwound with sutures or staples.

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Wound assessment

Consensus statement: At each visit, a thorough assessment of wound size, status and appearance should be conducted, documented and supported with photographs to monitor progress over time.

Wound assessment should cover the wound's location and dimensions (length, width and depth). If simple area measurements are being performed, the wound should be measured, starting with the longest length, followed by width, which is the widest measurement perpendicular to the length. However, simple length-by-width calculation is known to overestimate the wound area by as much as 41%, while digital planimetry produces more accurate results.[42] Several devices and digital applications are available for digital planimetry of wounds.

The wound bed should be documented according to the percentage covered with necrotic tissue (including eschar), slough, granulation tissue or epithelial tissue—including whether granulation tissue appears healthy (red and beefy), unhealthy (pink, grey and/or friable) or hypergranular (above surrounding skin level). The wound bed should also be examined (and probed with a sterile instrument) for the visible presence of exposed deep-tissue structures, such as dermis, subcutaneous fascia, capsule, muscle, tendon, joint capsule or bone, as well as undermining or tunnelling. The presence of malodour and the amount (none/low/medium/high), consistency (thin/moderate/thick) and type (serous, sanguineous and/or purulent) of exudate should be recorded. Wound-related pain, including location, intensity, quality and any aggravating or relieving factors, should also be assessed.[43]

Clinicians can be aided in recalling all the features of a wound to document with the acronym BM-PODD:

- Bed
- Margins
- Periwound
- Odour
- Drainage
- Dimensions.

The presence of any local signs of infection should also be assessed, including erythema, warmth and areas of fluctuance of the periwound skin and wound.[44] Patients who have diabetes may not present with local signs or symptoms of infection. Infection in these patients may present as hyperglycaemia, malaise (the 'diabetic foot flu') and increases in wound-related pain, exudate and malodour.[45]

Osteomyelitis (infection of the bone) should be suspected if bone is visible at the base of the wound or the wound probes to bone (PTB). However, visible bone and PTB are not definitive of an osteomyelitis diagnosis. A bone biopsy to obtain histological markers of infection is the gold standard for definitive diagnosis. However, magnetic resonance imaging (MRI) and X-ray imaging studies in combination with PTB and inflammatory markers can also be diagnostic for osteomyelitis.[46]

Wounds should be photographed at each visit, as visual images complement written documentation and provide a clear, immediate reference to evaluate healing progress. These photographs also improve interdisciplinary team communication and collaboration that can contribute to successful wound-care outcomes. Several wound photographic documentation programs also have measurement capabilities, helping to ensure consistent recording and evaluation of healing progress over time. The setting, exposure, background lighting and positioning when taking a wound photograph should also be standardised and remain consistent over time to optimise ongoing evaluation of the wound.[47]

Diagnostics

Consensus statement: Assessment for limb preservation can be supported with diagnostic modalities including laboratory tests, wound cultures, wound biopsies and imaging studies.

Laboratory tests

Standard laboratory tests to obtain in the work-up of a patient with a wound include a complete blood count with differential (CBC with diff), complete metabolic panel (CMP) and glycosylated haemoglobin (HbA1c) for patients with diabetes, prealbumin and homocysteine. Infection can be assessed with C-reactive protein (CRP), erythrocyte sedimentation rate (ESR) and procalcitonin (PCT).[45,46] Blood urea nitrogen (BUN) levels indicate renal function and fluid status and can be associated with delayed wound healing. A serum or urine nicotine test can also be ordered in patients who actively use tobacco/nicotine, to confirm patient report of tobacco/nicotine use, reduction or cessation (although there is a risk of falsely elevated results in nicotine replacement therapy).

Wound culture

Routine wound cultures should not be obtained from all wounds. As per international guidelines, wound cultures should only be obtained from wounds with suspected infection.[46,48] Wound cultures should be obtained from the deep tissue following debridement and sent for aerobic, anaerobic, fungal and atypical bacteria, depending on the severity of infection and suspected bacterial pathogens.[45,46] The use of topical or systematic antibiotic therapy for prophylaxis or to promote wound healing is not recommended for clinically uninfected wounds.[46] First-line identification of pathogens from wound cultures is best achieved through conventional techniques. These methods demonstrate strong concordance with molecular microbiology and next-generation sequencing in a shorter amount of time, and they are more cost-effective and reliable in the detection of clinically relevant, causative pathogens.[46]

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Wound biopsy

A biopsy of the wound is recommended for all wounds that the treating clinician judges as not having notably reduced in depth or size following 30 days of standard of care. A biopsy may be performed sooner than 30 days if a lack of reduction in wound depth and/or size is concerning prior to 30 days. Wounds that present with an atypical appearance or inconsistent wound history should also be biopsied. This is particularly important for wounds that do not fit into known categories of a hard-to-heal wound. The biopsy aims to identify the presence of malignancy to ensure appropriate referral to an oncology specialist. However, less invasive wound and skin cancers, such as squamous cell carcinoma, can be surgically excised without a referral.

Imaging

Radiographs are recommended for wounds near osseous prominences to evaluate for the presence of osteomyelitis. Additionally, radiographs can be helpful in the evaluation of deformities that contribute to the wound, such as osseous changes related to Charcot neuroarthropathy. Advanced imaging should be considered if there are any signs suggestive of infection, such as subcutaneous emphysema or osseous abnormalities relating to osteomyelitis, or if there are findings concerning for Charcot neuroarthropathy or other osseous abnormalities.

MRI is highly sensitive for the diagnosis of infection, including osteomyelitis. MRI for suspected osteomyelitis may be less reliable in the toes due to the thickness of imaging cuts and the smaller size of the phalanges.[49]

Computed tomography (CT) allows for evaluation of the location and extent of infection and osseous changes. It has the advantage of being widely and readily available at most medical facilities. Disadvantages include exposure of the patient to radiation, as well as lower sensitivity and specificity for evaluation of soft tissue infection and osteomyelitis compared with MRI.[49]

Ultrasound is a readily available, non-invasive and cost-effective imaging tool that can be used to evaluate the presence of space-occupying abscesses and early osseous changes related to osteomyelitis. However, it is not as sensitive as MRI and CT.[49,50]

Nuclear imaging modalities include traditional scintigraphy and white-blood cell labelled scans.[50] While traditional scintigraphy is highly sensitive for osseous activity, it is not specific for osseous activity related to infection alone.[49,50] The use of traditional scintigraphy in combination with a white-blood cell labelled scan can improve the specificity of results related to osseous infection.[49,50] Physiological CT imaging with 18-fluoro-deoxyglucose positron emission tomography (18-FDG-PET/CT) is also sensitive and specific for infection and has the advantages of being non-invasive and results not being hindered by the presence of metal implants or prior antibiotic use.[50]

Additional imaging studies that are specific to evaluating vascular status include an arterial duplex scan in patients with suspected PAD and a venous duplex scan in patients with suspected venous insufficiency.

Light imaging

Near-infrared spectroscopy (NIRS) is an innovative, non-invasive vascular diagnostic tool that uses imagery to quantitatively measure tissue oxygenation as a downstream measure of perfusion.[51] NIRS is not widely available, and its full utility in limb preservation is yet to be defined. However, studies have demonstrated that NIRS can assess local microvasculature to assist with guiding debridement, timing of CAMP application and preoperative planning for amputation.[51] NIRS may help infer wound healing status and has also been explored for infection assessment and response to compression therapy, hyperbaric oxygen therapy and vascular intervention.[51,52] Results obtained from NIRS should be evaluated in conjunction with other perfusion assessments.

Autofluorescence imaging is an emerging tool for assessing bacterial load in the wound bed and periwound skin.[53] While its availability remains limited, studies have demonstrated the high sensitivity and specificity of autofluorescence imaging for detecting bacterial load, particularly when bacterial concentrations reach or exceed 10^4 colony-forming units (CFUs).[53] Additionally, autofluorescence imaging has proven valuable in guiding optimal wound sampling for culture collection in cases of suspected infection and guiding wound debridement.[53]

CAMPs-specific considerations

Consensus statement: Clinicians are encouraged to evaluate the indications for a specific CAMP by consulting the product instructions for use as well as the relevant scientific literature. This approach will enhance informed product selection and optimise patient outcomes.

Absolute contraindications to CAMPs use include active untreated clinical infection; active malignancy at the wound site (with the exception of synthetics); and patients with known allergies or sensitivities to CAMP components.[54–58] Relative contraindications include inability to optimise the patient for CAMPs use; vascular compromise that has not been or cannot be addressed to optimise blood flow; post-surgical wound following resection of a malignant lesion with positive or uncertain margins; and patient preference due to religious or personal beliefs.[59–61]

When a specific CAMP is considered for limb preservation, this should be checked against the indications and contraindications outlined in the product's instructions for use. The wounds that can be treated by specific CAMPs can vary by several factors, including:

- Aetiology (pressure ulcers, venous leg ulcers (VLUs), DFU, surgical wounds or traumatic wounds)
- Depth (partial- and full-thickness wounds, tunnelling/undermining, sinus tracts, exposed tendon, muscle, joint capsule or bone)
- Duration with no response to conventional therapy (>3 weeks, >6 weeks or >4 months).[54–58]

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Consensus statement: If a limb is at risk of amputation but is suitable for preservation with CAMPs, the patient and their wound should undergo interdisciplinary optimisation of modifiable risk factors.

Interdisciplinary collaboration

Consensus statement: Patient and wound optimisation is best achieved with interdisciplinary collaboration.

Collaboration can be encouraged by implementing routine meetings of an interdisciplinary limb-preservation board to review patients with at-risk wounds.[62] An interdisciplinary care team for limb preservation can vary in composition and may include vascular surgeons, podiatrists, orthopaedic surgeons, plastic surgeons and interventional radiologists; occupational, physical and rehabilitation therapists; and specialists in wound care, nutrition, orthotics/prosthetics, endocrinology, diabetes and infectious disease, as well as those in general medicine, allied healthcare professions and social work.[32,63,64]

This interdisciplinary team can enhance healing outcomes by facilitating timely referral and interventions for patient and wound optimisation, reducing the number of interventions needed for healing and major amputation rates. Likewise, a collaborative approach can ensure the treatment plan is holistic and supports the patient's overall health.[64–67]

Support services should also encompass an interdisciplinary approach, incorporating educational provisions, practical advice and the thoughtful engagement of patient concerns. Furthermore, it is essential that these services extend to the patient's family and other significant individuals in their lives, ensuring they receive appropriate support and resources during the patient's wound-healing journey.[63]

Box 1. Principles of patient concordance

- Provide patient-centred education
- Prioritise the patient's needs and goals in clinical decision-making
- Encourage two-way communication with open dialogue
- Clearly explain the treatment options, including their risks and benefits
- Outline the supporting evidence base for each treatment option
- Respect the patient's right to choose, based on their values

Education and establishing concordance

Consensus statement: Successful limb preservation requires patient education, concordance and engagement.

Patients need to be educated on why their limb is at risk of amputation and the treatment options available to help preserve it. This should cover how those therapeutic interventions work to support healing and achieve their clinical goal; their relative risk and benefits, including potential complications; and the necessary time commitment and procedures. Education should be evidence-based, patient-focused and regularly reinforced. The information provided should be clear, concise and accessible, as well as ideally delivered in the patient's preferred language and format. A small qualitative research study found that communicating with clarity, empathy and sensitivity to the patient's cultural background promotes patient trust and resilience,[68] which is likely to enhance engagement.

Once a patient has been educated on limb preservation and demonstrated that they understand the requirements, the next step is to confirm whether they wish to pursue any of the available options. Providers should respect the patient's right to make their own informed choice based on their values system, following the principles of patient concordance (*Box 1*).[6]

Once a patient has agreed to begin limb preservation, the patient and provider should then engage in an open, collaborative dialogue to set and align clear treatment goals that define a successful outcome. This should draw on a patient-centred assessment that identifies any concerns the patient has about their limb. Active patient engagement and collaborative decision-making help build concordance, shared understanding and commitment to care plans. Making the patient a partner in their care enhances their overall experience and adherence to treatment, supporting better healing outcomes.

Treatment

A thorough and holistic patient assessment should guide the selection of appropriate interventions for limb preservation, based on the patient's individual needs. Limb preservation typically requires a multimodal treatment strategy that comprises multiple simultaneous interventions. Interventions to aid limb preservation can be broadly classed into four categories:

1. Patient/wound stabilisation and optimisation—including comorbidity management, vascular optimisation, infection control, nutritional supplementation and psychosocial

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support—are essential to manage the systemic processes underlying or exacerbating tissue loss and to enhance standard of care.

2. Foundational wound interventions—including wound-bed preparation (cleansing, debridement and moisture and bioburden management), as well as provision of gold-standard care (offloading in DFUs and pressure ulcers, and compression therapy in VLUs) to address the underlying aetiology—are essential to addressing local factors that are underlying or exacerbating tissue loss.

3. Advanced wound interventions—including negative pressure wound therapy (NPWT), oxygen therapy (topical or hyperbaric) and surgical intervention (flaps and grafts)—may be indicated where, following patient/wound stabilisation and optimisation, foundational wound interventions are insufficient to reverse tissue loss.

4. CAMPs—including autografts, allografts, xenografts, synthetic and bioengineered grafts—may be used alongside foundational or advanced wound interventions to promote restoration of lost tissue.

Successful limb preservation typically requires an appropriate combination of interventions. For example, patient/wound stabilisation and optimisation is required for foundational wound interventions to be effective. Moreover, advanced wound interventions should improve the healing capacity of foundational wound interventions when more complex support is required. Meanwhile, CAMPs can act as a supportive adjunct to a holistic wound-healing strategy.

Limb preservation is not always a straightforward, linear process, and the interventions initiated following the initial assessment may need to be modified to achieve the clinical objectives. Therefore, patients at risk of limb loss should be continually monitored. Any deterioration, stagnation or slow healing, or emergence of complications, should prompt a thorough reassessment. This should then guide a change of treatment strategy, which could involve amending existing and/or initiating new patient/wound stabilisation and optimisation interventions, as well as adjusting those for foundational wound care. Advanced wound interventions might also need to be initiated or adjusted, based on clinical judgement. Meanwhile, the complementary role of CAMPs means they should be considered alongside other wound interventions, whether foundational or advanced.

CAMPs are often used to take the wound to final closure, or to serve as a bridge to a state where surgical closure can be performed. The wound aetiology (i.e., atypical and acute/traumatic wounds) should not preclude CAMPs use, as any stabilised and optimised patient would benefit from faster wound healing. Early CAMP use is associated with faster wound healing, reduction in wound infections and avoidance of amputation.[69]

There is a wide range of CAMPs available for wound treatment, many of which exhibit overlapping or multifunctional effects.[1] Although direct comparative studies between different CAMPs are limited, several systematic reviews and meta-analyses support the effectiveness of each CAMP category in promoting wound healing and reducing the risk of amputation and other adverse events compared with standard of care alone.[70–73] Therefore, the selection of a specific CAMP should corresponded to its properties, mechanisms, indications and contraindications, guided by a comprehensive patient evaluation, the intended treatment goals and the level of follow-up care required.

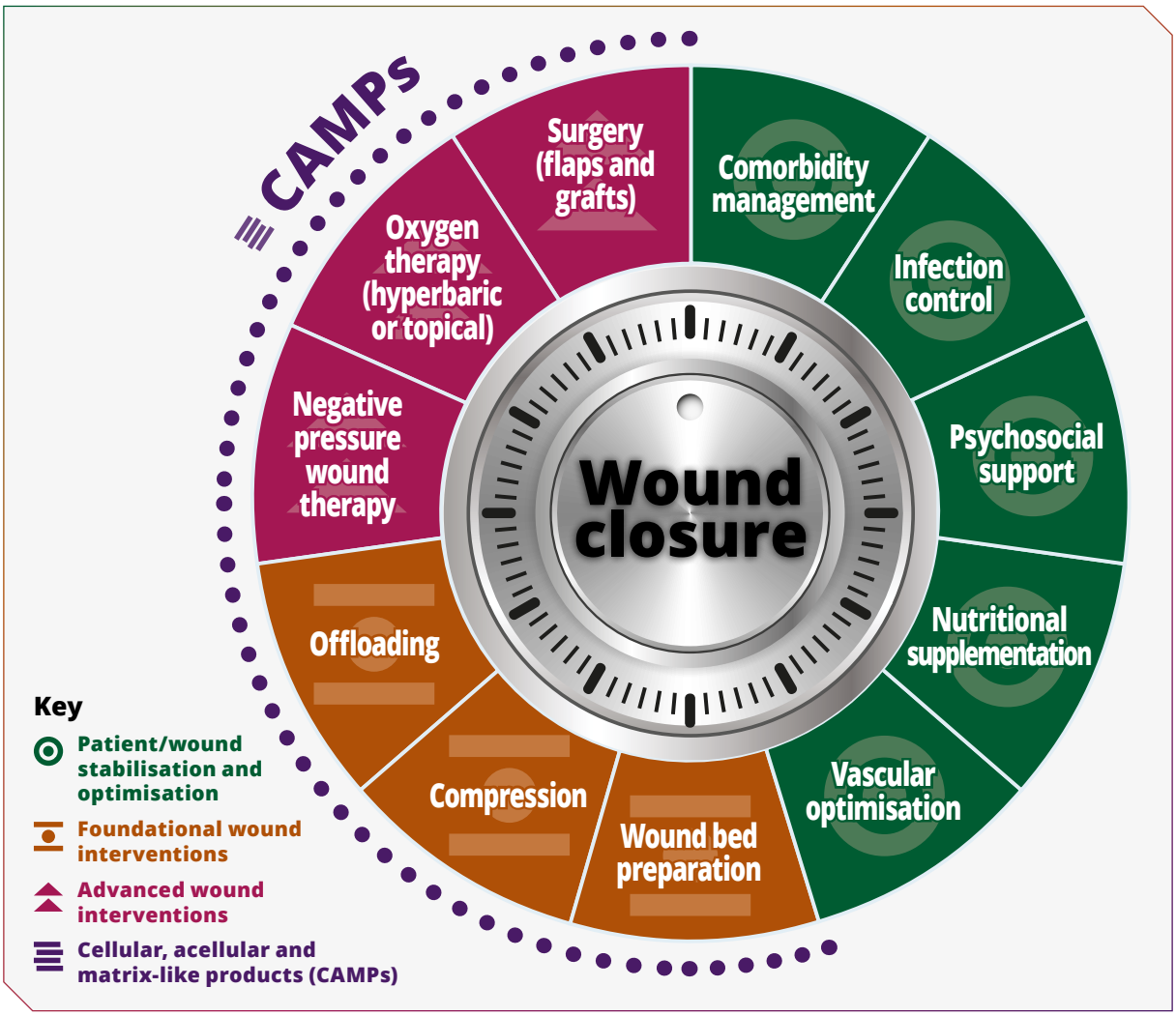
This approach to (re-)evaluating the treatment plan for limb preservation can be visualised as a dial, where the treating clinician's consideration moves across all current and potential interventions to ensure the optimal combination of options (*Figure 2*). This movement is multidirectional, going up to advanced options if indicated, but always able to return to patient/wound stabilisation and optimisation or foundational wound interventions to ensure that the basics are correctly covered. CAMPs sit alongside the edge of the dial as a reminder of their complementary value to other foundational or advanced wound interventions. The dial is intended to aid continuous, responsive re-evaluation of the patient across a potentially non-linear healing trajectory. This should allow for ongoing fluid personalisation and optimisation of their treatment regimen to achieve limb preservation.

Consensus statement: The dial of interventions for limb preservation can aid in organising a comprehensive assessment and treatment plan.

The use of CAMPs for wound resolution holds promise for enhancing limb function, improving patient quality of life and potentially reducing the risk of ulcer recurrence. A review of the US Medicare Limited Data Set for patients treated for diabetic lower-limb ulcers between 2015 and 2019 revealed improvements in quality-adjusted years of life.[74] However, due to the limited number of published studies, there is a clear need for further research to investigate the effects of early CAMP use on limb functionality, quality of life and wound recurrence rates.

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Figure 2. Dial of interventions for limb preservation

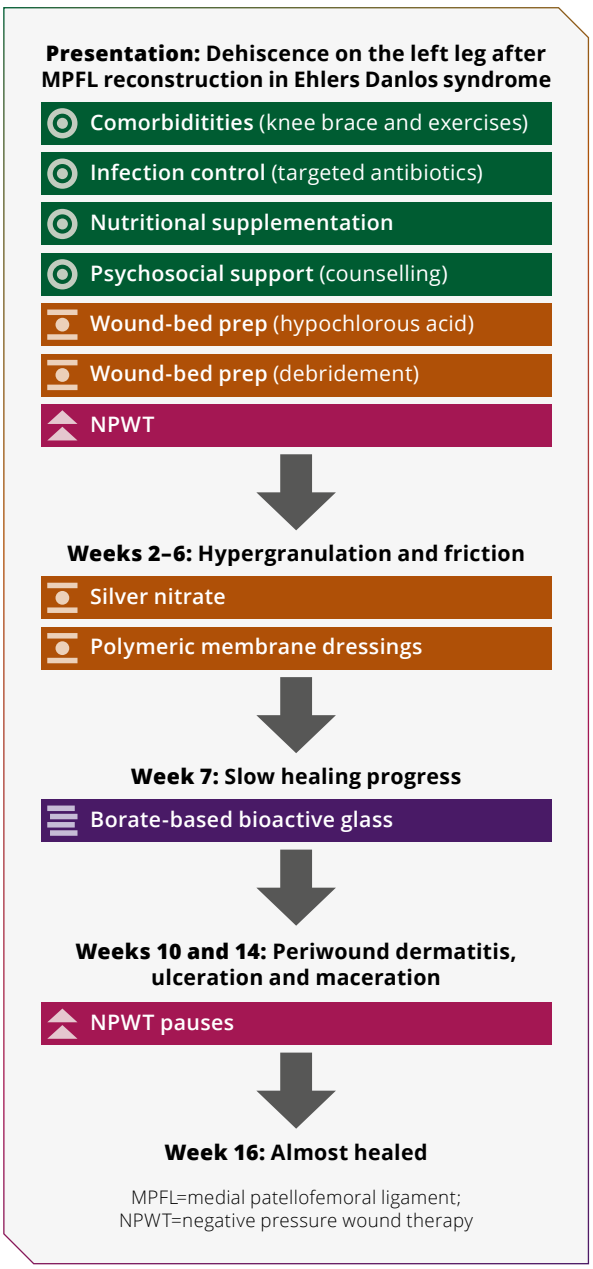


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CASE STUDIES

The following case studies illustrate a variety of personalised multimodal strategies for limb preservation. Each approach involves patient optimisation, foundational and advanced wound care and synergistic use of CAMPs. This approach is initiated based on a thorough holistic patient assessment, then adjusted according to equally thorough ongoing reassessments. Each case is illustrated with photographs and a visual representation of the treatment timeline.

Figure 3. Timeline of case study 1



MPFL=medial patellofemoral ligament; NPWT=negative pressure wound therapy

Case 1. Dehisced surgical wound treated with borate-based bioactive glass

Presentation

A 21-year-old woman with Ehlers Danlos syndrome underwent open medial patellofemoral ligament (MPFL) reconstruction and arthroscopic lateral release to repair her damaged left MPFL, help stabilise the patella and avoid dislocation (*Figures 3* and *4*). This followed an earlier left knee tibial tubercle osteotomy to correct patellar instability and pain. Her underlying Ehlers Danlossyndrome gave her highly elastic and fragile skin, with widened atrophic scars and hypermobile joints. This impeded wound healing.

Soon after suture removal and application of wound-closure strips, the patient noticed blistering and dehiscence of the surgical wound, as well as formation of necrosis of the periwound skin. At postoperative week 7, she was referred by the orthopaedics teams for wound care.

The wounds collectively measured 9.4×9.4×1.4 cm, and the wound bed showed eschar, slough and areas of pink granulation tissue, with moderate purulent exudate. The periwound skin was fragile and delicate.

The wound had never previously been cultured, and a deep-tissue wound culture demonstrated methicillin-sensitive *Staphylococcus aureus* (MSSA) and *Enterococcus*. Near-infrared spectroscopy (NIRS) showed that the tissue was well oxygenated.

Interventions

The MSSA was treated with 2 weeks of the oral antibiotic amoxiclav/augmentin. To optimise the patient, nutritional

Figure 4. Photographs of case study 1



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supplementation, comprising nutrition powder and protein shakes, was provided.

Foundational wound interventions comprised cleansing with hypochlorous acid and sharp debridement of necrotic tissue. Debridement left a deep full-thickness wound with exposed tendon. To promote granulation tissue, treatment was supplemented with NPWT, during the use of which the periwound was protected with barrier wipes. Topical treatment had begun with silver sulfadiazine, petrolatum gauze and antimicrobial honey gel, followed by collagenase ointment and petrolatum gauze, then non-adherent silicone with NPWT, as well as collagen as the wound progressed.

The patient, who wore a knee brace, was counselled to avoid exposing the knee to friction or pressure. Steps were taken to avoid pressure from her brace, ensuring that knee flexion did not put excessive tension on the wound. She was given range-of-motion physical therapy exercises to optimise full-knee flexion and minimise tension at the wound edges. The activity level recommended for her knee was modified based on wound progression. She was well supported at home and received financial assistance though the hospital while uninsured between jobs.

There was minimal wound progression over the next 6 weeks, despite provision of standard of care. At some follow-up visits during this time, the central wound showed hypergranulation, which was treated with silver nitrate. The patient also sometimes presented with friction blisters on her knee caused by tight clothing rubbing against the wound and its dressing. These were treated with polymeric membrane dressings.

By week 7, given the lack of progress, it was decided to supplement the foundational wound care with borate-based bioactive glass (BBG), in three applications. The BBG fibres were intended to enhance angiogenesis, stimulate cellular proliferation and provide a regenerative scaffold to facilitate quality tissue formation, as well as improve tensile strength and minimise scarring in a patient with fragile skin. The fibres, which dissolve on contact with tissue, conform to the wound bed and can be applied over exposed hardware.

By week 10, the shallower medial ulcer had closed. There were several occurrences of periwound breakdown and recurrent ulceration in the remaining ulcer. At week 12, the patient presented with periwound dermatitis. It was therefore necessary to pause NPWT to prevent further irritation and breakdown. A moisture barrier cream was instead used for 1 week until skin integrity was restored.

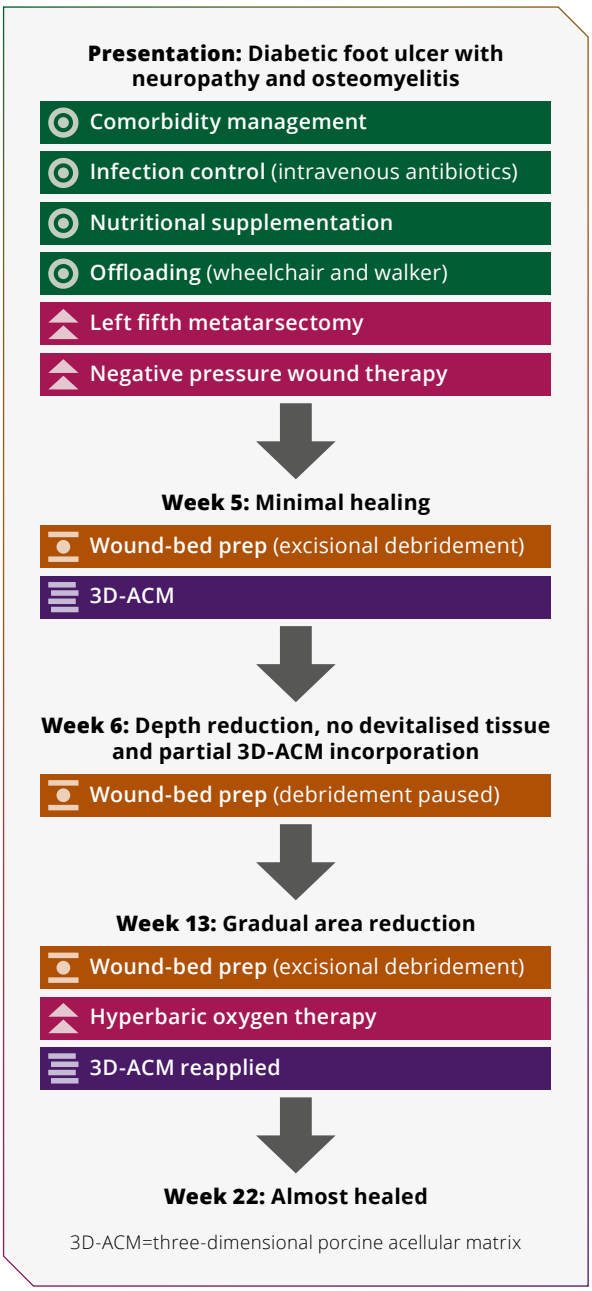
The remaining wounds improved, and NPWT was discontinued after 2 weeks. By postoperative week 22, they were close to 100% re-epithelialisation. The patient, who was not a good surgical candidate (with the risk of exposed hardware), was able to avoid the need for a graft or flap.

Case 2. Diabetic foot ulcer treated with a three-dimensional porcine acellular matrix

Presentation

A 65-year-old man presented with a DFU on the left lateral foot that had persisted for over a year and was complicated by osteomyelitis (*Figures 5* and *6*). His medical history included type 2 diabetes with neuropathy, hyperlipidaemia, coronary artery disease, obstructive sleep apnoea and iron-deficiency anaemia. He had previously undergone multiple foot surgeries, including incision and drainage, left fifth toe amputation and left fifth metatarsal amputation.

Figure 5. Timeline of case study 2



3D-ACM=three-dimensional porcine acellular matrix

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Figure 6. Photographs of case study 2



The DFU measured 10×5×3.2 cm and probed to bone. It was malodourous with purulent exudate, and protective sensation was absent (Wagner Grade 3; W2 I0 F3). The patient's vascular status was normal, confirmed by arterial studies and NIRS. Radiographic imaging revealed cortical erosion and bone marrow oedema of the remaining fifth metatarsal, consistent with osteomyelitis.

Interventions

The patient underwent left fifth metatarsectomy with tendon transfer and bone biopsy, resulting in a 10.5×5.5×3 cm postoperative wound with exposed bone, devitalised tissue and slough. Comorbidities were optimised through medical management, nutritional supplementation and a high-protein diet. A 6-week course of intravenous, culture-directed antibiotics was administered to treat infection. Foundational wound care included debridement and offloading with a controlled ankle motion (CAM) walker and wheelchair. NPWT was initiated due to wound depth and exposed structure.

By postoperative week 3, the wound measured 10×4×2.4 cm. At week 5, excisional debridement was performed, and a three-dimensional porcine acellular matrix (3D-ACM) was applied.

After 10 days (postoperative week 6), the wound measured 9.5×3.4×0.3 cm, an 85% depth reduction but less than a 50% area reduction. No devitalised tissue was observed. The 3D-ACM showed partial incorporation and a spongy texture, so it was left in place under continued NPWT without further debridement.

At 56 days after the first 3D-ACM application (postoperative week 13), the wound measured 7×2×1 cm. The initial 3D-ACM had largely incorporated, prompting excisional debridement and application of a second 3D-ACM. Between weeks 13 and 21, approximately 40 sessions of adjunctive hyperbaric oxygen therapy (HBOT) were administered after completion of evaluation and approval. HBOT was used to promote angiogenesis, fibroblast proliferation, and granulation and capillary budding, while enhancing leukocyte function and antibiotic efficacy. HBOT has been shown to be effective in patients with Wagner grade ≥3 DFUs, and it is synergistic with antibiotics increasing intracellular penetration, improving control in chronic osteomyelitis and reducing major amputation rates.[46]

At 63 days after the second 3D-ACM application (postoperative week 22), the wound achieved near-complete epithelialisation.

Case 3. Necrotising fasciitis treated with viable cryopreserved umbilical tissue

Presentation

A 63-year-old woman presented with a DFU on the right foot with uncontrolled necrotising fasciitis infection, present for nearly 1 week (*Figures 7* and *8*). There was extensive gangrene and tissue necrosis of the plantar surface of the foot; gangrene of the fourth and fifth digits; and partial plantar gangrene of the second and third digits. She had type 1 diabetes, chronic kidney disease (managed with dialysis and nephrology) and anaemia (managed by haematology as an inpatient). The patient had adequate circulation.

Interventions

Intravenous antibiotics were administered to control systemic infection and bioburden. The wound was managed with repeated sharp debridement. Meanwhile, the hospital nutritionist prescribed 250 mg of vitamin C three times a day.

The patient did not respond to the antibiotics, and after less than a week, she was facing a below-knee amputation. The fourth and fifth toes were far too gangrenous to preserve, and these smallest digits were amputated to save the wider limb.

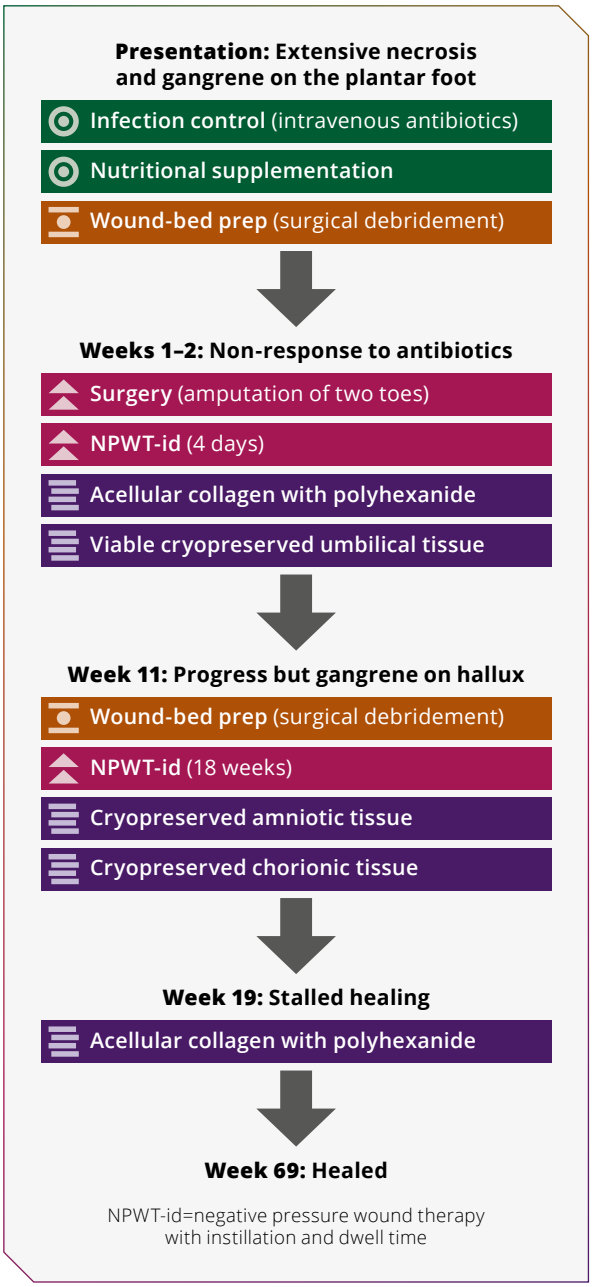
The remaining necrotic tissue and gangrene was surgically debrided. This foundational wound intervention was supplemented with NPWT with instillation and dwell time (NPWT-id) and a sheet of acellular collagen with polyhexanide, to manage the infection.

NPWT-id was stopped after 4 days, and the wound subjected to sharp dissection. A viable cryopreserved umbilical tissue (vCUT), a cellular amnion-and-chorion CAMP, was applied once only to initiate closure.

Progress was made over the next 8 weeks (week 11), when the patient was discharged to an extended care facility. However, 1 week later, there was notable gangrene of the hallux, likely caused by excessive pressure from a dressing. The dorsal tissue was still viable. First, the gangrene was debrided. Then, cryopreserved chorionic tissue (CVCT) was applied on the hallux subdermally to promote angiogenesis across the deficit

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Figure 7. Timeline of case study 3



and stimulate migration of the peripheral mature cells into the wound. Cryopreserved amniotic tissue (CVAT) was applied across the CVCT as a source of epidermal growth factor to help regenerate the lost tissue and stimulate epidermal closure. NPWT-id was then re-initiated.

By week 19, the plantar wound had stalled, likely as a result of bioburden. It was sharp debrided, and another sheet of acellular collagen with polyhexanide was applied to address the bioburden.

At 38 weeks after presentation, the wounds were steadily healing, with full healing achieved at week 69.

Figure 8. Photographs of case study 3



After this, the tissue on the hallux and foot continued to regenerate. CAMP application, combined with interdisciplinary teamwork, commitment and compliance, preserved the patient's foot and leg.

Case 4. Gangrenous hallux treated with viable cryopreserved placental membrane

Presentation

A 52-year-old man with diabetes presented with a gangrenous DFU on the hallux that had developed from a blister. He had been referred for hallux amputation (*Figures 9* and *10*). However, he wished to preserve the toe, if possible, especially because he was afraid that losing his hallux would prevent him from climbing ladders effectively, which was essential for his job as a supervisor of a helicopter manufacturing company. The wound measured 5.1×3.4×0.1 cm and was filled with dry gangrene.

Interventions

To stabilise the patient, his vascular status was optimised; his diabetes control was improved; and his nutrition was supplemented with vitamin C 500 mg. The wound was surgically debrided, with minimal peripheral bleeding. This

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Figure 9. Timeline of case study 4

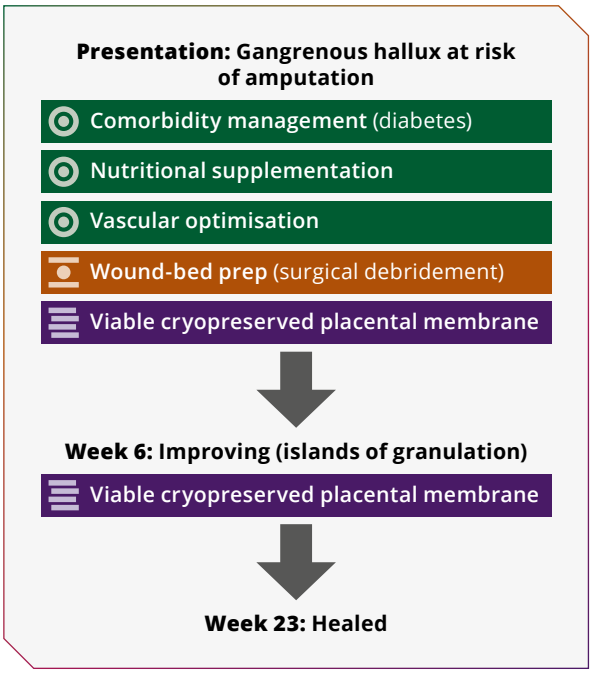


Figure 10. Photographs of case study 4



was followed by application of a cellular viable cryopreserved placental membrane (vCPM).

At week 6, there were islands of granulation tissue, demonstrating angiogenesis. The wound was sharp debrided, and vCPM was reapplied. After this, the tissue continued to regenerate, and the wound achieved complete closure by week 23.

Case 5. Traumatic foot wound treated with viable cryopreserved umbilical tissue

Presentation

A 27-year-old man presented to the emergency department with a traumatic wound to his left foot following a motorcycle accident (*Figures 11* and *12*). The trauma had ripped out all five metatarsals, along with the adjacent skin and the neuro-vascular and musculo-tendonous structures. The tissue deficit was large: the first metatarsal was exposed, and all five digits were limp and laterally displaced due to dislocation from the metatarsals.

Figure 11. Timeline of case study 5

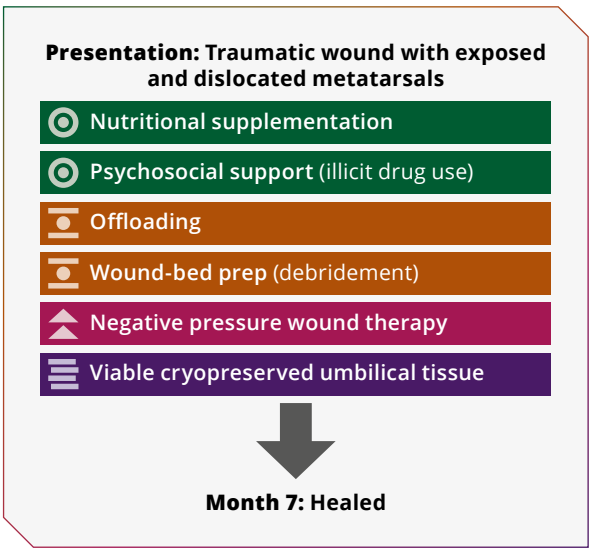


Figure 12. Photographs of case study 5



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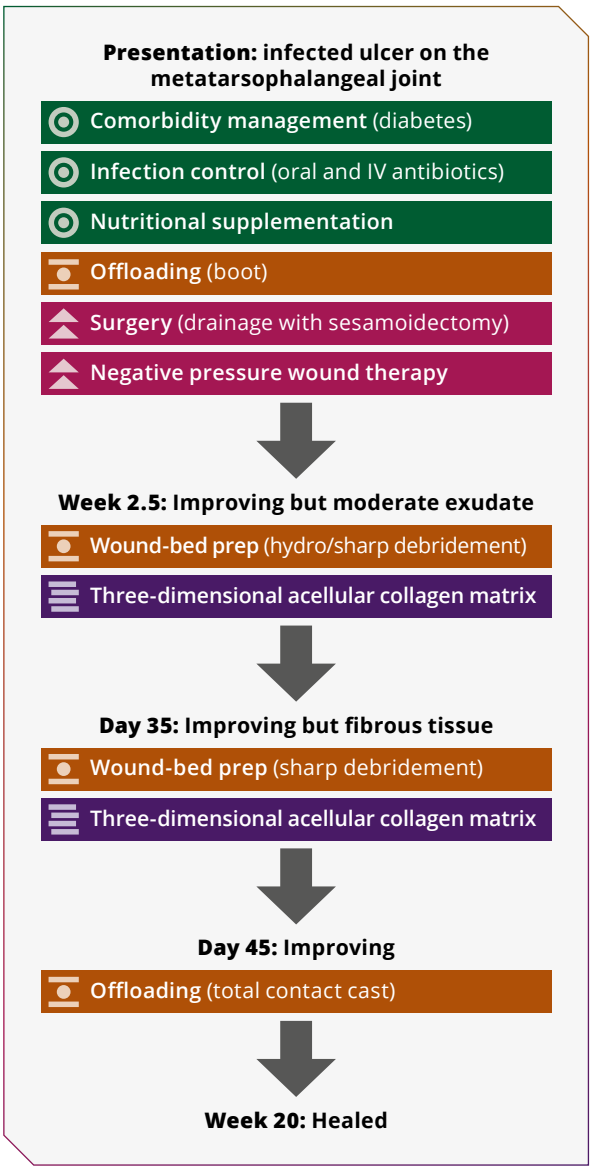
Based on evaluation of the bone and soft tissue loss, a below-knee amputation was recommended, which the patient refused. He was transferred to another hospital, where he agreed to an attempt to preserve his toes before undergoing a transmetatarsal amputation.

Interventions

Patient stabilisation and optimisation comprised vitamin C 500 mg three times a day as a nutritional supplement and counselling on illicit drug use for psychosocial support.

There was a critical need for extensive tissue regeneration to preserve the foot. To accomplish this, 3 days post-trauma, the wound underwent surgical debridement, NPWT and a single application of cellular vCUT. The patient received offloading to take weight off his foot,

Figure 13. Timeline of case study 6



By month 7, the wound was brought to closure. Treatment was successful, and foot amputation was avoided. Eventually, the patient could wriggle his toes and function well in his shoe.

Case 6. Chronic foot abscess treated with a three-dimensional porcine acellular collagen matrix

Presentation

A 50-year-old woman with diabetes, neuropathy and a structural foot deformity presented with a 2-month-old plantar DFU and cellulitis of the right first metatarsophalangeal joint (MPJ) (*Figures 13* and *14*). She had self-treated using topical antiseptics and a CAM boot. Imaging confirmed subcutaneous fluid consistent with an abscess at the plantar first MPJ, accompanied by oedema of the lateral sesamoid, as well as clinical evidence of undermining, necrosis, serosanguineous drainage and peripheral cellulitis.

Interventions

The patient was stabilised through glycaemic control, nutritional supplementation and antibiotic therapy (oral preoperatively and intravenous postoperatively). She underwent operative incision and drainage with lateral sesamoidectomy to decompress the abscess and relieve plantar pressure. NPWT was initiated postoperatively but discontinued after discharge due to insurance limitations.

At the 2.5-week follow-up, hydrosurgical and sharp debridement were performed. After debridement, the wound measured 2.0×2.2 cm and was 2.0 cm deep, with moderate exudate. A hepatic-derived porcine 3D-ACM was applied for its thickness, conformability and ability to achieve full-wall

Figure 14. Photographs of case study 6



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apposition. Dressings included a non-adherent mesh, supportive strips and an antimicrobial alginate, with a double-layer tubular bandage for compression. The CAM boot was maintained to permit daily dressing changes due to high exudate levels.

Weekly follow-ups included excisional sharp debridement and standard dressings, with steady granulation and contraction observed.

After 35 days, the wound had reduced to 1.5×1.5 cm and 0.5 cm depth. Fibrous tissue formation prompted curette debridement and reapplication of 3D-ACM.

At day 45, the wound measured 1.2×1.1 cm with 0.3 cm depth, and the CAM boot was replaced with a total contact cast to reduce shearing and pressure on the wound area.

By day 87 (week 12), full epithelialisation was achieved.

Case 7. Longstanding post-amputation wound treated with an acellular dermal matrix

Presentation

A 52-year-old man presented with a hard-to-heal postoperative wound of 34 years (*Figures 15* and *16*). The wound occurred following amputation of most of his left foot, after an accident when his foot got caught in a railway track during a dangerous game. He had seen several doctors in his rural area, and the stump had been reconstructed with skin grafts, but one area had never healed, and he had 'learned to live with it'. He had a history of hypercholesterolemia and hypertension and moderately smoked and consumed alcohol. The patient had adequate vascularity (ankle brachial index of 1.0 and palpable pulses) and nutrition (prealbumin 22 mg/dl and albumin 4.4 g/dl), and there was no evidence of infection.

After sharp debridement, the wound measured 4.8×3.2×1.6 cm, and the wound bed was covered with 70% yellow fibrotic devitalised tissue and 30% granulation tissue. It was surrounded by osseous prominences.

Interventions

The hypercholesterolemia and hypertension were well controlled with atorvastatin 20 mg and lisinopril 5 mg daily. The patient was educated on the detrimental effects of nicotine on wound healing, and he was presented with a treatment plan, including the anticipated duration, outcome and required adherence to smoking cessation, offloading and other instructions. He gave his informed verbal consent, and offloading was provided with a removable cast walker. Sharp debridement was performed weekly.

The next stage of treatment began 4 weeks later, once the patient had demonstrated his commitment to the treatment plan and the patient and wound were deemed optimised for CAMP application. First, the wound underwent sharp debridement with scalpel, forceps and curette. Then, an acellular dermal matrix was applied and held in place using suture and staples. A CAMP was selected that could cover the wide and deep tissue deficit, act as a barrier against the external environment and stimulate angiogenesis and matrix production.

After this, continuous NPWT at 75 mmHg was used as an adjunctive therapy and bolster dressing to keep the CAMP in place and avoid seroma or haematoma formation, although

Figure 15. Timeline of case study 7

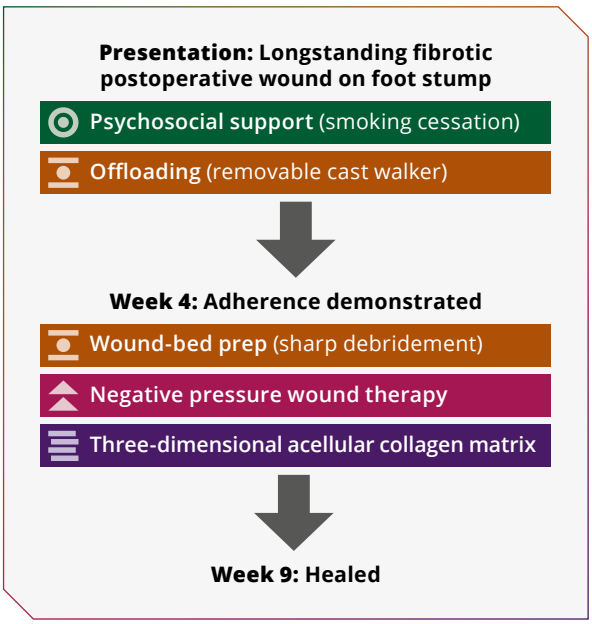


Figure 16. Photographs of case study 7



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the bony prominences around the wound rendered NPWT less effective in facilitating granulation tissue formation.

The wound healed over the following weeks and had closed 9 weeks after a single application of the CAMP. Such rapid closure of a wound that had been static for 34 year was attributable to both the availability of CAMPs and the patient's dedication to working with his care team to achieve healing goals, especially through smoking cessation and ongoing use of the removable cast walker.

Case 8. Post-revascularisation amputation site treated with cryopreserved umbilical tissue and cryopreserved placental membrane

Presentation

A 74-year-old man presented with a hard-to-heal wound of 6 months on the distal tip of the left second toe (*Figures 17* and *18*). He had a complex medical history, including peripheral arterial disease, type 2 diabetes and foot gangrene, as well as stroke, transient ischaemic attack, chronic diastolic heart failure and coronary artery disease status following three coronary artery bypass grafts. The wound measured around 0.5×0.5 cm, with a fibrogranular wound bed containing a mixture of healthy red granulation tissue and areas of adherent yellow fibrin. There was minimal serosanguinous exudate and no purulent discharge or odour. The ulcer was positive to probe-to-bone, indicating exposure of underlying osseous structures.

Interventions

A left second toe open amputation was performed to eliminate the infection. Following surgery, tubular support bandages were used for compression, and a CAM boot was provided for offloading. He was seen biweekly for continued local care and to ensure that the dry gangrenous tissue did not turn into wet gangrene.

Various methods were implemented to stabilise and optimise the wound and patient. The day following amputation, to improve limb perfusion and preserve his foot, the patient underwent deep venous arterialisation (DVA) of the left lower limb. For diabetes management, he was referred to the endocrinologist and placed on metformin, with his glycated haemoglobin decreasing to 5.9. The patient's family provided him with psychosocial support.

In the weeks after revascularisation, despite adherence to offloading, the patient experienced progressive tissue loss. His distal forefoot turned necrotic with gangrenous changes affecting his hallux and third toe. The second toe amputation site developed a fibronecrotic wound base, with macerated wound borders.

At 10 weeks post-revascularisation, the patient's entire forefoot was necrotic, with wet gangrene in the forefoot. His vascular status was reassessed, and he then underwent two-stage open guillotine transmetatarsal amputation on the

Figure 17. Timeline of case study 8

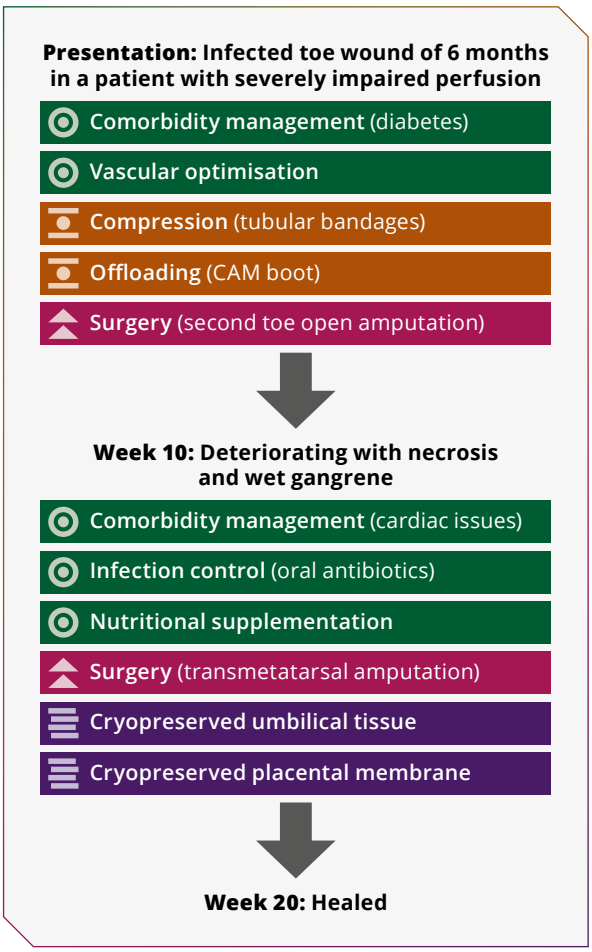


Figure 18. Photographs of case study 8



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left foot to stabilise the wound, with application of a CAMP to the amputation site to enhance healing, promote granulation and reduce risk of infection in a high-risk vascular patient. This began with disarticulation at the metatarsal-phalangeal joints and application of vCUT, followed by metatarsal resection with application of vCPM in the outpatient clinic 2 days later. The CAMP was applied weekly, with his dressing left in place until the next visit. Revisiting the stabilisation and optimisation strategy, he was placed on a high-protein diet to optimise wound healing, as well as on 2 weeks of oral antibiotics for skin and soft tissue coverage. He was also followed by the endocrinology, vascular and cardiology teams, for diabetes, peripheral arterial disease and heart failure, respectively, the latter proving well controlled by medication.

The wound healed within 20 weeks, showing how a combination of advanced surgical techniques and CAMPs can help to avoid a lower-limb amputation in a complex multimorbid case.

Case 9. Burn treated with cryopreserved umbilical tissue and cryopreserved placental membrane

Presentation

A 58-year-old woman presented with a hard-to-heal burn on the right knee from airbag deployment that had been present for 3 months (*Figures 19* and *20*). She had significant comorbidities, including type 2 diabetes and hypertension, and smoked six cigarettes a day. The wound measured approximately 28×19×0.3 cm, and had an irregular, fibrogranular wound bed, partially covered with moist and loosely adherent slough. There was moderate serosanguinous exudate. Her pulses were palpable, indicating sufficient vascular supply.

Interventions

Initial treatment was provided weekly at a local wound care centre. At month 3 after the accident, the wound remained unhealed. Due to the size, severity and chronic nature of the wound and the patient's high-risk profile, she was referred for advanced wound care. Surgical debridement was performed, followed by application of vCUT, which would be reapplied 2 weeks later. NPWT was used throughout to bolster the CAMPs, which were otherwise kept in place with elastic tubular support bandages, also used for compression.

Her diabetes was managed by endocrinology with semaglutide, and her glycated haemoglobin was lowered. Her hypertension was managed with hydrochlorothiazide. To promote wound healing, she was also invited to join a smoking cessation group and encouraged to maintain a high-protein diet, and she proved adherent to these recommendations.

After 2 months of advanced wound care (month 5 post-injury), following wound debridement, a vCPM was applied to the wound, followed by non-adherent silicone, bolster, absorbent and gauze dressings. The CAMP was applied 20 times, with gradual healing progress over the next 24 weeks, at which point the wound had healed (month 10 post-injury). The use of CAMPs supported tissue regeneration in a static wound where conventional care had been ineffective, underscoring the importance and effectiveness of regenerative therapies in limb preservation and wound healing.

Figure 19. Timeline of case study 9

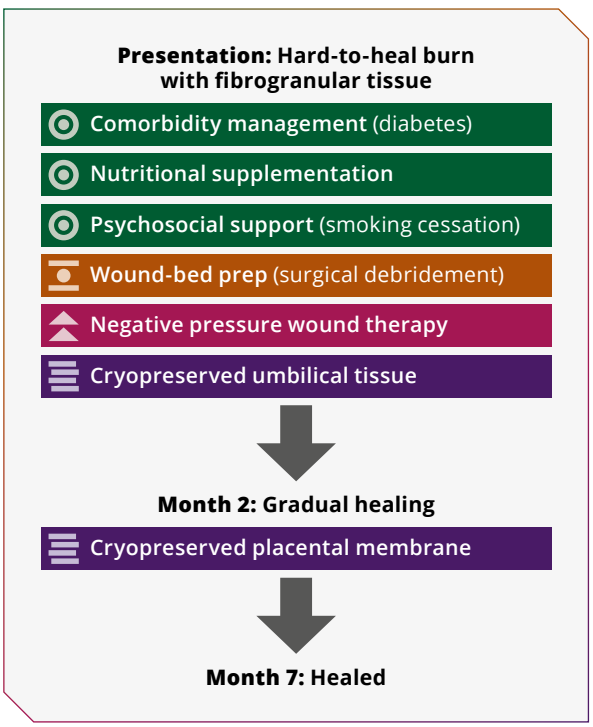


Figure 20. Photographs of case study 9



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Case 10. Necrotising fasciitis treated with an amniotic tissue-based CAMP

Presentation

A 72-year-old woman presented with severe necrotising fasciitis on the back of her leg, following a scratch from a thorn in this area (*Figures 21* and *22*). It was an acute infection, without relevant comorbidities.

Interventions

On admission to the hospital, the patient was placed on intravenous vancomycin to manage the necrotising fasciitis. Then she was taken to the operating room, where aggressive excision and debridement of the contaminated tissues was performed. Following this, she underwent multiple split-thickness skin grafts (STSGs) intended to fully close the wounds on her lower leg.

At week 8, there was an area around the right medial ankle that did not heal. The plastic surgeon advised against performing another skin graft due to the patient's frailty and the considerable amount of tissue that had already been removed.

Complete wound closure was achieved after four weekly applications of an amniotic tissue-based CAMP.

Figure 21. Timeline of case study 10

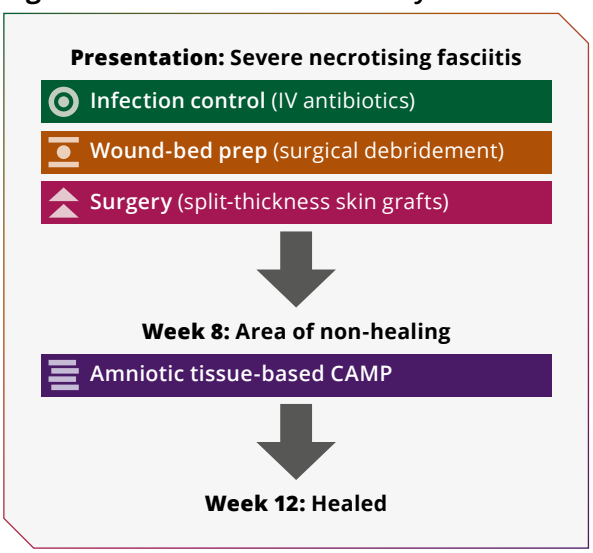


Figure 22. Photographs of case study 10



Case 11. Heel ulcer and osteomyelitis treated with an acellular dermal matrix

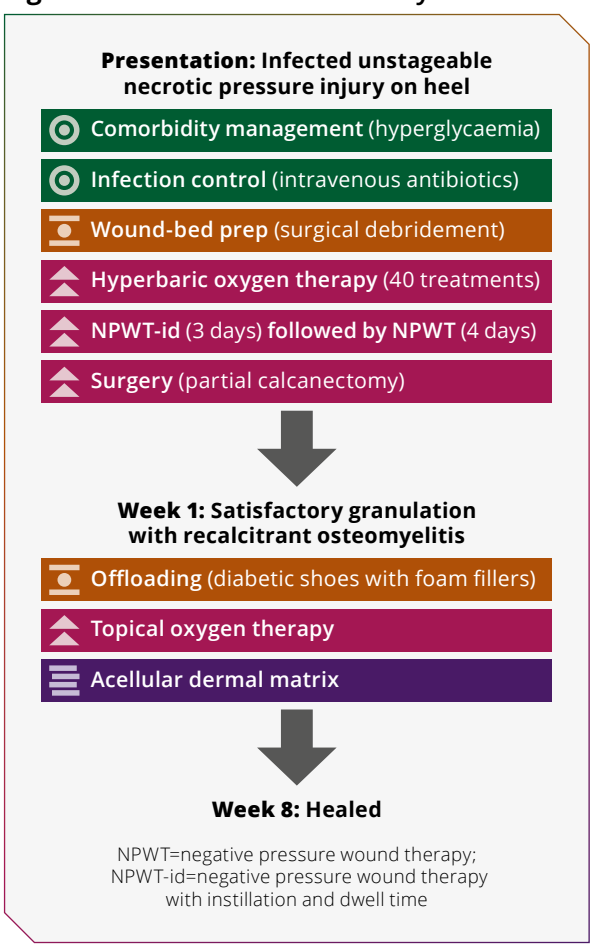
Presentation

A 56-year-old man presented to the emergency department with a pressure injury (PI) of unknown origin on his right heel (*Figures 23* and *24*). The patient had uncontrolled type 1 diabetes, hypertension and end-stage kidney disease. The PI was unstageable, covered in necrotic tissue and had been malodorous and exuding with purulence for 4 days. There was no pain, and a monofilament test did not incur a protective sensation. The patient had fever, chills, an ABI of 0.98 and an oral temperature of 38°C. Radiographic findings included bony erosion and oedema in the calcaneus. Severe cellulitis and osteomyelitis of the calcaneus and heel were suspected.

Interventions

The patient was hospitalised for a multi-step limb-preservation strategy due to osteomyelitis. The treatment began with intravenous broad-spectrum antibiotics (vancomycin 1 g and piperacillin/tazobactam daily for 4 weeks) and included surgical debridement along with a partial calcanectomy, during which a bone biopsy was performed. The internal medicine team worked in tandem to control the patient's hyperglycaemia and hypertension.

Figure 23. Timeline of case study 11

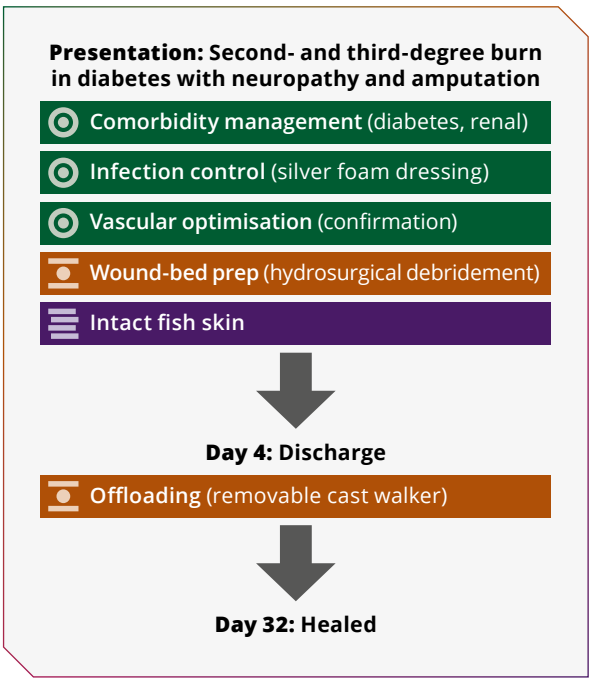


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Figure 24. Photographs of case study 11



Figure 25. Timeline of case study 12



To manage bioburden and promote granulation tissue formation, NPWT-id was implemented. On day 3, the patient was discharged with traditional NPWT.

After 1 week, following satisfactory granulation of the wound, both NPWT-id and NPWT were discontinued. However, due to the persistent nature of the osteomyelitis, the patient underwent 40 treatments of HBOT.

Upon completing this regimen, topical oxygen therapy was initiated, and an acellular dermal matrix was applied weekly to facilitate complete wound closure. By week 8, the wound had closed completely without significant postoperative complications. The patient was then transitioned into custom extra-depth diabetic shoes with foam fillers.

Case 12. Second- and third-degree burn treated with intact fish skin

Presentation

A 52-year-old man presented to the podiatry clinic with a burn of the right foot from placing his foot under hot water in a bath after the water heater had been adjusted (*Figures 25* and *26*). The patient had type 2 diabetes with peripheral neuropathy and a left below-the-knee amputation secondary to complications of diabetes. Diabetes was well-controlled on insulin and oral medications, with a glycated haemoglobin of 5.4%. He had received a renal transplant and was taking anti-rejection medication. On the date of injury, he placed his right foot under the running hot water which he determined to be too hot based on the steam and subsequently adjusted the temperature before continuing his bath. There was no pain. After the bath, he put his boots on and went to work. During the workday, friction caused large bullae to form on the dorsal foot, and one ruptured in his shoe. After returning from work, he noticed the injury and presented to the podiatry clinic the next morning. The burn was staged as second and third degree. Clinical vascular exam and non-invasive vascular studies revealed sufficient perfusion for wound healing.

Figure 26. Photographs of case study 12



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Interventions

The patient was admitted to the hospital and taken to the operating room for hydrosurgical debridement. The bullae and nonviable tissue were debrided from the wound, leaving a clean, bleeding wound bed free of signs of infection, as well as showing that part of the wound extended into the subcutaneous tissue. The wound's acute status and large surface area prompted a decision to apply a 2:1 meshed intact fish skin graft, which was prepared, placed over the wound and stapled at the time of surgery. Any excess CAMP overlying the wound margins was trimmed and discarded. The CAMP was covered with a silver-impregnated silicone foam to prevent infection. The wound was evaluated daily to monitor for signs of infection and graft effectiveness on wound healing.

The patient was discharged from the hospital on day 4 and continued with home dressing changes every 2 days. He was dispensed a removable cast walker for immobilisation. He returned to the podiatry clinic weekly for local wound care, consisting of debridement and monitoring until the wound healed on day 32. After 6 months, there was good skin coverage with minimal scarring. Use of CAMPs had helped the wound heal by secondary intention from the bed upward, rather than by surface contraction.

Case 13. Open amputations treated with intact fish skin as a bridge to grafting

Presentation

An 82-year-old man was admitted to the hospital after he developed cardiogenic shock and became hypertensive following a coronary artery bypass (*Figures 27* and *28*). He was transferred to intensive care and placed on vasopressors. Over the next 3 weeks of intensive care, he developed vasopressor necrosis of the toes and distal feet. After vasopressors were stopped and the patient was stabilised, the toes were determined to be unsalvageable due to the extent of gangrene. No peripheral arterial disease was present on non-invasive vascular studies, and the gangrene was dry and uninfected.

Interventions

The patient underwent bilateral transmetatarsal amputations with an open guillotine technique, due to the lack of adequate soft tissue to close and the ability for the patient to be ambulatory immediately after surgery to continue rehabilitation. After open amputation, metatarsal diaphyses 1–5 were exposed in the surgical wounds at the distal stumps. Intact fish skin meshed 2:1 was prepared and applied to cover the bone and deeper soft tissue of the open amputations as a bridge to STSG. The CAMPs were bolstered with NPWT, without an interface between the CAMP, and open-cell reticular foam to promote granulation tissue. The first NPWT change was 5 days later, then subsequently twice a week. The patient was placed in HBOT at 2.4 ATA for 90 minutes daily while an inpatient to prevent necrosis of the marginal tissue. The patient was allowed to ambulate with physical therapy in bilateral removable cast walkers and placed in heel offloading boots while in bed to prevent pressure injuries.

Figure 27. Timeline of case study 13

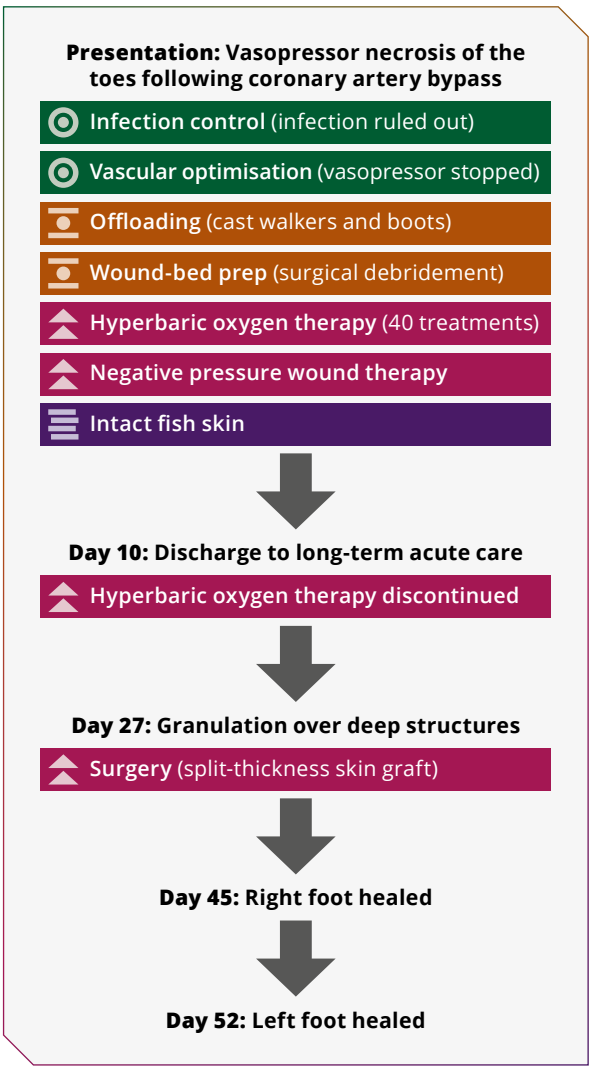
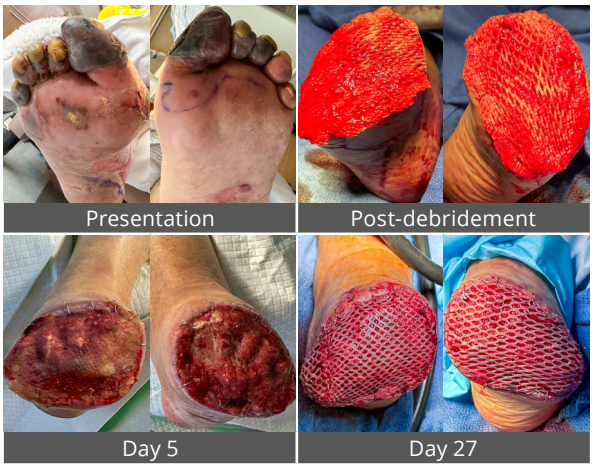


Figure 28. Photographs of case study 13



The patient remained an inpatient for his cardiac care for 9 days after CAMP application and then transferred to

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long-term acute care. NPWT, offloading and physical therapy was continued during this time. After 27 days, the goal of CAMP application was met, as amputation sites and deeper structures were covered with healthy granulation tissue. A STSG was then applied to the bilateral amputation sites, covered with a silicone contact layer, and bolstered with NPWT, which remained in place for 5 days. The right foot was fully epithelialised 18 days after STSG, and the left foot was fully epithelialised at 25 days. No subsequent infection or complications occurred during healing.

Case 14. Necrotising fasciitis treated with hypothermically stored amniotic membrane

Presentation

A 60-year-old man presented with a gangrenous left second toe and necrotising fasciitis in the left plantar foot (*Figures 29* and *30*). He had uncontrolled neuropathic diabetes, with blood glucose at 292 mg/dl on admission, as well as hypertension and cardiac issues.

Interventions

On admission, the patient underwent extensive incision and drainage, along with an amputation of the second toe. The patient's insulin level was adjusted to manage the diabetes, and he was administered intravenous antibiotics (vancomycin, piperacillin+tazobactam and metronidazole) for the infection; his hypertension and cardiac issues were controlled with lisinopril and carvedilol, respectively.

Figure 29. Timeline of case study 14

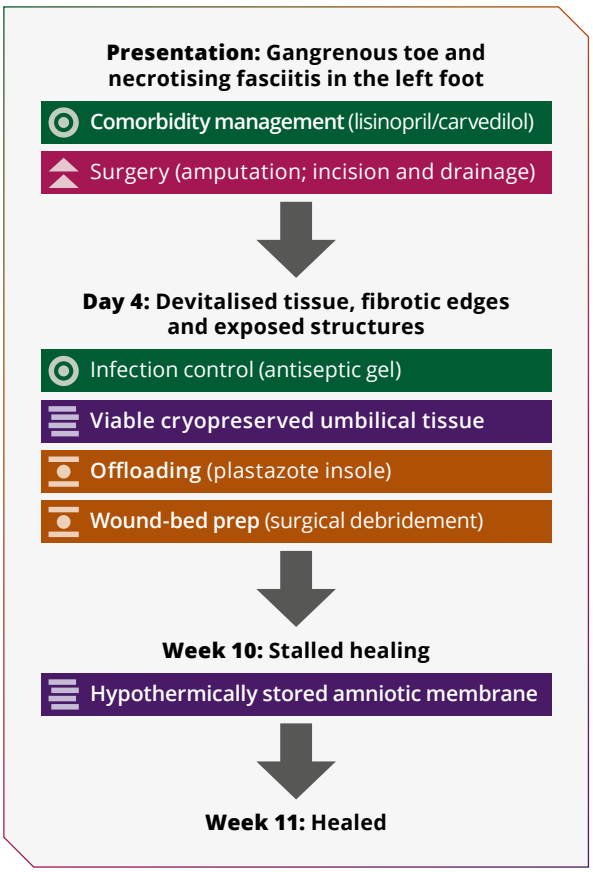


Figure 30. Photographs of case study 14



On day 4, the patient's wound measured 11.8×7.6×1.8 cm, with devitalised tissue, fibrotic edges and exposed subcutaneous tissue, muscle and fascia, as well as a high level of serous exudate. The wound underwent surgical debridement and application of antiseptic polyhexanide gel, followed by vCUT, which was reapplied at week 5. He was provided with a plastazote insole for offloading, to which he was adherent.

The wound improved over the following weeks, reducing in depth, with minimal exudate. However, by week 10, the improvement had stalled, showing fibrotic edges with a hyperkeratotic rim. It was determined that the vCUT had exhausted its growth factors and collagen. Therefore, hypothermically stored amniotic membrane (HSAM) was applied to support healing.

A week after the first and only HSAM application, the wound had epithelialised, with visible skin lines demonstrating remodelling (week 11). It remained healed at 10 months.

Case 15. Diabetic foot ulcer treated with bilayered living cellular construct and hypothermically stored amniotic membrane

Presentation

A 49-year-old man with neuropathic diabetes underwent amputation of the right hallux due to a longstanding infected hard-to-heal wound (*Figures 31* and *32*). He had neuropathic diabetes, with blood glucose of 162 mg/dl. Over the following weeks, his amputation wound underwent mechanical debridement and was dressed with native collagen and polyhexanide gel. His diabetes was more closely monitored by an endocrinologist, and he was started on vitamin B complex to address the neuropathy.

By week 6, it was evident that the wound was not healing, and he was referred for a transmetatarsal amputation to accelerate healing of the remaining foot. However, it was instead decided to try to preserve the limb, based on previous successes.

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Figure 31. Timeline of case study 15

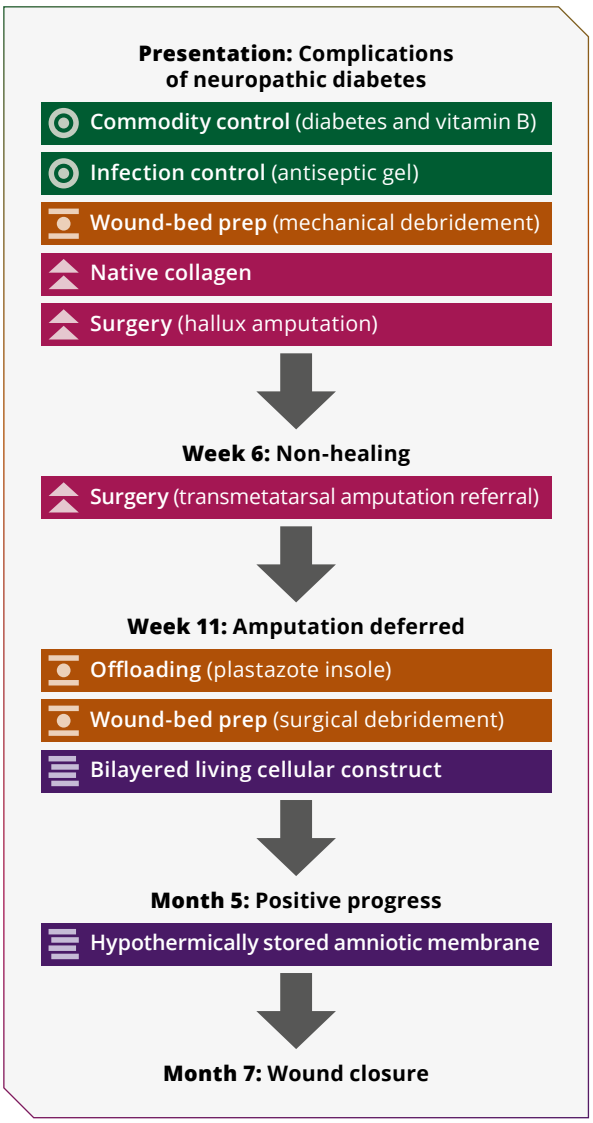


Figure 32. Photographs of case study 15



Interventions

At week 11 after presentation, the wound measured 7.6×3.9×0.3 cm with a fibrotic devitalised wound bed suggestive of a high bioburden. It was surgically debrided and treated with bilayered living cellular construct (BLCC), selected for its capacity to accelerate healing and suitable coverage for large wounds. A second application of BLCC was applied 2 weeks later (month 3) where it was noted the wound began to close significantly. BLCC was applied for the maximum five times, with delays in applications due to the patient missing appointments. Full offloading was also provided.

At 11 weeks after the first BLCC application (month 5), the CAMP had met its expectations, and the patient was transitioned to HSAM. HSAM was applied for a total of three times, and on month 7 the wound was closed. The wound remained closed 3 months later (month 10), and the limb was preserved.

Case 16. Stump wound in diabetes and peripheral vascular disease treated with a bilayered living cellular construct

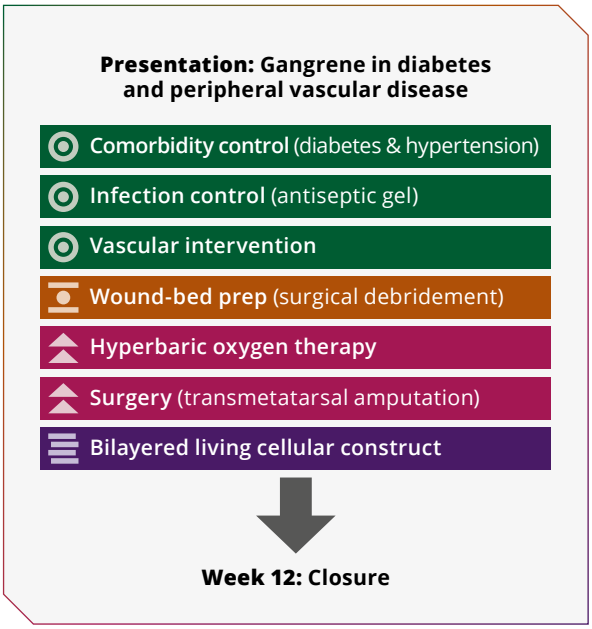
Presentation

A 74-year-old woman presented with gangrene of all five toes on the left foot (*Figures 33* and *34*). She had neuropathic diabetes, with comorbid peripheral vascular disease, hypertension and other cardiac issues.

Interventions

The patient underwent guillotine transmetatarsal amputation, leaving a 6.9×6.6×0.3 cm stump wound with a fibrotic bed with scattered necrotic tissue. At this point, her ABI was 0.6.

Figure 33. Timeline of case study 16



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A multimodal limb-preservation strategy was undertaken to minimise the high risk of further limb loss.

The wound was surgically debrided, followed by application of BLCC, selected for its large coverage area and effectiveness at promoting closure. Vascular intervention for peripheral vascular disease was also performed. Because the wound was classified as Wagner 4, had a bone infection and had a failed flap, healing was supported with hyperbaric oxygen therapy for 12 weeks. Meanwhile, the patient's diabetes, cardiac issues and hypertension were managed as required.

BLCC was reapplied at weeks 4 and 7, with consistent improvement noted at each application. The wound closed in 12 weeks.

Figure 34. Photographs of case study 16



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CONCLUSION

This international consensus document underscores the importance of comprehensive, patient-centred assessment as the foundation for successful limb preservation. Patient history, physical examination and diagnostic testing must be carefully evaluated to determine whether preservation is feasible and to identify modifiable risk factors that can be optimised prior to CAMP use. By integrating CAMPs within a holistic framework of stabilisation, foundational wound interventions and advanced therapies, clinicians can personalise treatment to optimise healing outcomes while minimising the risk of amputation.

Interdisciplinary collaboration is central to this approach. Regular engagement among members of the care team ensures timely referral, comprehensive optimisation and integrated treatment strategies. Patient education and concordance are also essential; individuals must understand their treatment options, risks and responsibilities to participate meaningfully in their care. Such partnership fosters adherence, resilience and trust, thus enhancing overall wellbeing.

CAMPs have the potential to accelerate wound closure, reduce recurrence and improve patient function and quality of life. They can also help prepare the wound for skin grafting. Early use of CAMPs can help accelerate healing, reduce infection and avoid amputation.[69] Although comparative studies remain limited, ongoing clinical and observational data continue to reinforce their therapeutic value across diverse wound types. Further research is warranted to define the optimal timing, long-term outcomes and cost-effectiveness of CAMP use. In the meantime, this expert consensus provides a pragmatic, evidence-informed framework to guide healthcare teams in integrating CAMPs into comprehensive limb-preservation strategies. **JWC**

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APPENDIX 1. CHECKLIST OF ASSESSMENT FACTORS FOR LIMB PRESERVATION

Use this checklist to identify factors that can impact the feasibility of limb preservation. Ensure each checked factor is fully detailed in the assessment notes and carefully considered before attempting limb preservation with CAMPs.

Patient history

Medical history

Note specific diagnosis and duration

- ☐ Diabetes
  - ☐ Retinopathy
  - ☐ Neuropathy
  - ☐ Nephropathy
- ☐ Cardiovascular disease (e.g., congestive heart failure, myocardial infarction, stroke/transient ischaemic attack)
- ☐ Anaemia
- ☐ Obesity (body mass index ≥30)
- ☐ Immunological disease (e.g., rheumatoid arthritis or systemic lupus erythematous)
- ☐ Cancer

Medication history

Note duration and dose

- ☐ Non-steroidal anti-inflammatory drugs
- ☐ Steroids
- ☐ Immune modulators
- ☐ Antibiotics

Patient and psychosocial factors

Nicotine, alcohol and drugs

Note amount and duration

- ☐ Nicotine/tobacco use
- ☐ Alcohol consumption
- ☐ Illicit drug use

General wellbeing

- ☐ Limited mobility (note if bedbound, wheelchair bound or ambulatory with an assistive device)
- ☐ Low physical activity
- ☐ Inadequate support system
- ☐ Mental health condition (note diagnosis and duration)

Living environment

- ☐ Barefoot walking at home
- ☐ Stair-only access at home
- ☐ Lack of wheelchair access at home

Employment

- ☐ In employment
- ☐ Standing required at work
- ☐ Steel-toed or safety shoes required at work

Nutrition

- ☐ Insufficient dietary intake
- ☐ Inability to eat independently
- ☐ Disordered relationship with food
- ☐ Limited access to food
- ☐ Dietary restrictions
- ☐ Medication-related dietary limitations

Wound-specific history

- ☐ Longstanding hard-to-heal wound (note date first noticed by the patient and date first treated by a provider)
- ☐ Delayed healing despite prior wound treatments (note timeline of specific treatments)

Physical assessment

Vascular assessment

Visual vascular signs

- ☐ Cigarette odour
- ☐ Tar staining of the fingers or nails
- ☐ Surgical scars consistent with previous vascular procedures/surgeries on the neck, chest, abdomen and lower extremities
- ☐ Scars from previously healed wounds
- ☐ Atrophic skin or lack of digital hair growth
- ☐ Amputated limbs or digits

Femoral artery (FA)

- ☐ Non-palpable pulse in FA
- ☐ Inaudible Doppler examination in FA
- ☐ Bruit present in FA

Popliteal artery (PA)

- ☐ Non-palpable pulse in PA
- ☐ Inaudible Doppler examination in PA

Dorsalis pedis artery (DPA)

- ☐ Non-palpable pulse in DPA
- ☐ Inaudible Doppler examination in DPA
- ☐ Monophasic or biphasic waveform in DPA

Posterior tibial artery (PTA)

- ☐ Non-palpable pulse in PTA
- ☐ Inaudible Doppler examination in PTA
- ☐ Monophasic or biphasic waveform in PTA

Brachial indices

- ☐ Ankle brachial index (ABI) <1.0
- ☐ Toe brachial index (TBI) <0.7

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Neurological assessment

☐ Loss of protective sensation

Musculoskeletal assessment

Function

☐ Gait abnormality

☐ Understrength muscle (note grade and quadrant)

☐ Limited ankle dorsiflexion

☐ Limited first metatarsophalangeal dorsiflexion

Foot deformity

☐ Charcot foot/rocker-bottom deformity

☐ Bunion contributing to wound

☐ Hammertoe contributing to wound

☐ Other deformity contributing to wound (note type and area)

Dermatological assessment

☐ Frail or fragile overall skin quality

☐ Fungal infection (onychomycosis)

☐ Evidence of previous wounds

Wound assessment

Wound size

☐ **Large wound** (note length and width)

☐ **Deep wound** (note depth)

Devitalised tissue on wound bed

note percentages

☐ Necrotic tissue

☐ Slough

☐ Unhealthy granulation tissue

☐ Hypergranulation

Structures visible on wound bed

☐ Dermis

☐ Subcutaneous fascia

☐ Capsule

☐ Tendon

☐ Bone

Wound impact

☐ **Pain** (note level out of 10)

☐ Odour

☐ Excess exudate (note amount, consistency and type)

Periwound skin

☐ Erythema

☐ Oedema

☐ Warmth

☐ Areas of fluctuance

Diagnostics

Abnormal laboratory test results

☐ Complete blood count (CBC) with abnormal results

☐ Complete metabolic panel (CMP) with abnormal results

☐ Glycosylated haemoglobin (HbA1c) indicating insufficient glycaemic control

☐ Prealbumin test indicating malnutrition

☐ C-reactive protein (CRP) indicating infection

☐ Erythrocyte sedimentation rate (ESR) indicating infection and inflammation

☐ Serum nicotine indicating nicotine use

Wound culture and biopsy

Consider if the wound has not reduced in depth and/or size following 30 days of appropriate care

☐ Wound culture indicating infection

☐ Wound biopsy indicating malignancy or atypical wound aetiology

Imaging

☐ Radiograph indicating osteomyelitis, osseous prominences or other osseous changes

☐ Ultrasound indicating abscesses or osseous changes

☐ Magnetic resonance imaging (MRI) indicating infection

☐ Computed tomography (CT) indicating infection or osseous changes

☐ Arterial duplex scan indicating peripheral arterial disease

☐ Venous duplex scan indicating venous insufficiency

Light imaging (if available)

☐ Near-infrared spectroscopy indicating poor perfusion

☐ Fluorescence imaging indicating raised bioburden

CAMPs-specific considerations

☐ Allergy to specific CAMP components

☐ Cultural or religious objections to use of specific CAMPs

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