Bovine-derived collagen matrix as an adjunct in stage 3 pressure injuries: a case series of lower extremity wounds

Objective: Hard-to-heal (chronic) stage 3 pressure injuries (PIs) in medically complex patients are often refractory to standard treatments, and pose significant risks of infection, limb loss and diminished quality of life. Adjunctive use of advanced biologic materials, such as bovine-derived collagen matrices, may support more efficient wound resolution in these high-risk populations.
Method: In this retrospective case series, patients with hard-to-heal stage 3 PIs of the lower extremity were treated with a single application of a bovine-derived collagen matrix as part of a multidisciplinary wound care protocol. All patients had significant comorbidities, including diabetes and dementia, as well as mobility impairments, such as peripheral neuropathy and multiple sclerosis with paraplegia. Interventions included debridement, a single application of a bovine-derived collagen matrix, appropriate wound dressings and pressure offloading.
Results: All three patients (each with one PI) had failed to respond to prior standard wound care and their PIs had persisted from four weeks to approximately three years before treatment. Following a single application of the collagen matrix, complete wound closure was achieved within 27–52 days. Early wound responses were notable: one PI showed a 98% area reduction by day 14, another reduced by 76% by day 6, and in Case 2, closed by primary intention, stable closure was observed as early as day 3. No repeat applications of the bovine-derived collagen matrix were required, and no complications or recurrences were observed at follow-up.
Conclusion: This case series highlights the potential of bovine-derived collagen matrix as an effective adjunct to comprehensive wound care in medically complex patients with stage 3 PIs that have persisted for several months to years, despite prior standard treatments. In all cases, complete wound closure was achieved following a single application of collagen matrix, highlighting its potential utility in the management of hard-to-heal PIs. Further prospective studies are warranted to validate these outcomes.
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adjunctive wound therapy • bovine-derived extracellular matrix • collagen-based matrix • complex comorbidities • hard-to-heal wound • lower extremity ulcer • stage 3 pressure injury • wound • wound care • wound dressing • wound healing

Pressure injuries (PIs), also referred to as bedsores, decubitus ulcers or pressure ulcers (PUs), are localised injuries to the skin and underlying soft tissue resulting from prolonged pressure and shear forces, predominantly over bony prominences.[1] In 2016, the National Pressure Injury Advisory Panel (NPIAP) introduced updated terminology, recommending the term 'pressure injury' to better reflect the full spectrum of tissue damage, including stages that occur before visible skin breakdown.[2] Although the term 'pressure ulcer' remains in common use, it is important to note that incidences of non-uniform loading, not just direct pressure, can cause reduced blood flow to the affected area and shear deformation of tissue, potentially leading to injury.[3] Symptoms include redness, pain and open sores, which can progress to deep wounds exposing muscle and bone.[4]

The development of PIs is complex and multifactorial, involving the interplay of intrinsic and extrinsic factors. Extrinsically, prolonged pressure, friction, shear forces and moisture contribute to tissue deformation and ischaemia.[1] Internally, a range of factors, including comorbidities such as diabetes, vascular and cardiovascular disease, neurologic disorders (e.g., multiple sclerosis (MS), peripheral neuropathy), malnutrition, anaemia, dehydration and impaired perfusion compromise tissue integrity and accelerate breakdown.[1] PIs result from sustained mechanical loading, including compression, tension and shear, that induce cellular deformation, ischaemia and soft tissue necrosis.[5] The risk is particularly high in individuals with limited mobility, such as older people, patients who are bedbound or individuals who are wheelchair-dependent. Additional contributors include hypotension, prolonged anaesthesia, recent surgery, and the use of medications (e.g., sedatives, vasopressors, corticosteroids and analgesics) that impair mobility, sensory feedback and circulation.[4,6,7] In healthcare settings, especially nursing

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Scott R Boynton,[1] DPM, FACFAS; **Melina Butuci**,[2] PhD; **R Allyn Forsyth**,[2,3] PhD; **Sara Shahbazi**,[2] PhD, MSPH*
***Corresponding author email:** sshahbazi@mimedx.com
1 Oregon Health and Science University, Portland, OR, US. **2** MIMEDX Group, Inc., Marietta, GA, US. **3** Department of Biology, San Diego State University, San Diego, California, US.

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homes, PIs remain a significant concern due to the high prevalence of frailty, immobility and chronic disease.

There are four recognised stages of PIs, classified by the NPIAP, based on the depth of tissue involvement.[1]

1. Stage 1 is characterised by intact skin with non-blanchable erythema
2. Stage 2 involves partial-thickness skin loss affecting the epidermis and dermis
3. Stage 3 involves full-thickness tissue loss that extends into the subcutaneous layer, without exposing muscle or bone
4. Stage 4 includes deeper tissue loss with visible exposure of muscle, bone or supporting structures.[1]

In addition to these, unstageable injuries involve full-thickness tissue loss where the wound bed is obscured by slough or eschar. Deep tissue PI is a separate category marked by persistent, non-blanchable, deep red, maroon or purple discolouration, typically resulting from pressure and shear at the bone–muscle interface.[1]

In patients with comorbidities or mobility impairments, these wounds often resist standard therapies due to impaired perfusion, repeated pressure, delayed immune response, poor tissue regeneration, and reduced ability of the patient to manage their care effectively. In the absence of timely and appropriate intervention, hard-to-heal PIs may undergo progressive staging, resulting in high healthcare costs, prolonged hospitalisation, deterioration in physical and psychological health, increased risk of infection and sepsis, and, in severe cases, extensive tissue destruction, limb loss or death.[8–11]

An estimated 2.5 million new cases of PIs occur annually in the US, representing the second-most common diagnosis across the national healthcare system.[11] The clinical and economic burden of PI management is substantial. Treatment costs per case vary widely—from approximately $20,900 to $151,700 USD, depending on severity. The annual national expenditure is estimated at around $26.8 billion USD.[11,12] Stage 4 PIs, in particular, are associated with average hospital costs exceeding $124,000 USD per episode and add more than $11 billion USD to healthcare expenditures each year.[13] Healing trajectories are often prolonged; approximately 50% of stage 2 PIs and up to 95% of stage 3 and 4 PIs fail to achieve closure within eight weeks.[13] Moreover, stage 3 and 4 ulcers are frequently complicated by deep tissue infections, such as bacteraemia and osteomyelitis, which may become life-threatening without timely and advanced intervention.[13] Patients with PIs have increased healthcare use, including significantly higher 30-day hospital readmission rates, and experience a 2.81-fold increase in in-hospital mortality.[14,15] According to US Centers for Disease Control and Prevention estimates, approximately 60,000 deaths annually in the US are attributable to PI-related complications, underscoring their critical impact on morbidity and mortality within vulnerable populations.[11]

PIs most commonly develop over bony prominences subjected to prolonged pressure, such as the hips, sacrum, coccyx and heels, but can also occur on the feet and ankles.[16] When present in these locations, they may cause significant discomfort, pain and functional impairment. Foot-related PIs are particularly concerning due to their tendency to progress quickly and their impact on ambulation and quality of life (QoL). The heel is recognised as the second-most common site for PI development, but ulcers can form on any part of the foot. Contributing factors include poorly fitted footwear, prolonged pressure from bed sheets or mattresses, and limited offloading.[17] As discussed earlier, underlying chronic conditions, such as diabetes, peripheral artery disease and autoimmune diseases, can further compromise skin integrity and increase the risk of ulcer development.

Current standards of care (SoC) for PI management include cleaning, debridement to remove the necrotic tissues, and dressings to provide a moist wound environment. Addressing underlying aetiologies—such as correcting nutritional deficiencies and implementing frequent repositioning to offload pressure—is equally important to promoting tissue repair and preventing progression.[18] Advanced treatments, such as negative pressure wound therapy, cellular and tissue-based products, and surgical intervention, are often required for patients with stage 3 or 4 PIs, hard-to-heal wounds, or those with complicating factors, such as infection, extensive tissue loss or underlying comorbidities, that impair healing.[18,19] As the stage of a PI advances, achieving wound closure and meeting clinical goals become increasingly challenging. The presence of chronic conditions can further complicate treatment by interfering with the body's natural healing processes, impairing circulation, reducing immune response, and compromising tissue regeneration. Management becomes challenging in cases involving deep or tunnelling wounds, infection, heavy exudate, persistent inflammation, elevated proteolytic enzyme activity, and exposure of bone or muscle tissue.[18,19]

Bovine-derived collagen matrices have demonstrated efficacy as biological scaffolds in the treatment of hard-to-heal wounds, including PIs.[20,21] These matrices provide a structural framework that supports cellular infiltration, angiogenesis and extracellular matrix remodelling. By facilitating the body's natural fibroblast migration and deposition of new granulation tissue, collagen-based products contribute to the re-establishment of a functional dermal layer.[20,21] Their low immunogenicity, biocompatibility and ability to sequester proteases make them particularly useful in wounds that are stalled in the inflammatory phase or exhibit high proteolytic burden.[20,21] Several studies have evaluated the clinical efficacy of collagen dressings in hard-to-heal wound management.[22–26] A systematic review and meta-analysis encompassing 11 randomised controlled trials (RCTs) with a total of 961 patients found that the addition of collagen dressings to SoC significantly improved wound closure rates and reduced time to closure compared with SoC alone.[27]

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More recently introduced for clinical use, the advanced bovine-derived collagen matrix HELIOGEN (MIMEDX Group Inc., US) is indicated for the management of moderately to heavily exudating wounds and to control minor bleeding. HELIOGEN may be used for the management of exudating wounds such as PUs, venous stasis ulcers, diabetic ulcers, acute wounds (such as traumatic and surgical wounds) and partial-thickness burns. It contains type I and type III collagen, providing a matrix that supports cell adhesion and migration into the wound site, thereby promoting re-epithelialisation and wound closure.[28] The matrix also possesses intrinsic haemostatic properties that assist in controlling minor bleeding. Its absorbent nature allows for effective management of wound exudate while maintaining a moist environment, optimal for closure. The matrix may be applied dry or in a hydrated paste form, depending on the clinical need.[28]

This case series evaluates the effectiveness of a single application of bovine collagen matrices for hard-to-heal stage 3 PIs in medically complex patients with multiple comorbidities and significant mobility impairments, where the extent of full-thickness tissue loss conferred a high risk for secondary infection, delayed wound closure, and progression to more severe tissue damage and escalation of wound severity.

Method

Patient selection

Patients with hard-to-heal stage 3 PIs on the foot or lower extremity were retrospectively identified from a single physician practice in the US, with all procedures performed by the same attending surgeon. All patients exhibited profound mobility impairments and multiple comorbidities known to impair wound healing. The inclusion criteria were as follows:

- Stage 3 PIs, classified according to NPIAP guidelines, characterised by full-thickness tissue loss
- Hard-to-heal ulcers refractory to SoC therapies
- Underlying conditions impairing wound healing, e.g., MS, diabetes, neuropathy, dementia or prior amputations
- Wounds located on high-pressure areas of the foot or lower extremity, including metatarsal heads and amputation stumps.

Ethical statement and patient consent

All procedures were performed in accordance with the ethical standards of the respective institutions involved and the 1964 Declaration of Helsinki and its later amendments or comparable ethical standards. Institutional review board (IRB) approval was not applicable, as the study involved a retrospective review of data from three deidentified patients. This meets common criteria for exemption from IRB review, as such small case series are not considered human subjects under U.S. federal regulations (45 CFR 46.102).[29]

Written informed consent was gained from the patients for the publication of photographs and use of their data with the understanding that this information may be made publicly available.

Treatment protocol

All patients underwent initial surgical preparation, which included sharp debridement of devitalised tissue. In two cases, additional offloading surgical procedures were performed (fifth metatarsal head resection or exostectomy) to relieve localised pressure. After achieving a clean, viable wound bed with evidence of active bleeding, a single application of dry bovine-derived collagen matrix (500mg, single-use unit) was made to the wound surface. Following collagen matrix application, the wounds were dressed with a non-adherent layer (e.g., Adaptic (CURITY; Cardinal Health, US)), sterile gauze, and secured with a Kerlix (Bulkee II; Medline Industries, China) gauze wrap to maintain a moist wound environment. In one patient, wound edges were re-approximated with sutures to facilitate closure.

Postoperatively, all patients were maintained on strict non-weight-bearing protocols using wheelchairs, controlled ankle motion (CAM) boots or diabetic healing footwear, as appropriate, to ensure pressure offloading at the wound site. Patients were instructed on offloading strategies and monitored regularly with serial wound assessments to evaluate closure progression. No additional applications of extracellular matrix were performed.

Outcome measures

The primary outcome was the time to complete wound closure, defined as full re-epithelialisation with no drainage and no need for further surgical intervention. The secondary outcomes included the presence or absence of wound-related complications, such as secondary infection, wound dehiscence, or the need for additional surgical procedures (e.g., amputation), as well as the durability of closure observed during follow-up when available.

Statistical analysis

Descriptive statistics were used to summarise patient and wound characteristics, time to wound closure, and the absence of complications. No inferential statistical analyses were performed due to the small sample size.

Results

Demographics and wound characteristics of the three included patients are outlined in Table 1. The patients, with hard-to-heal stage 3 PIs of the foot or lower extremity, were treated with a single application of collagen matrix following wound bed preparation. All patients had significant comorbidities, including MS, diabetes, peripheral neuropathy and dementia, as well as profound mobility impairments.

Initial wound sizes ranged from 2.0×1.5×0.5cm to 4.5×4.5×1.0cm. Wound locations included the lateral plantar aspect of a transmetatarsal amputation (TMA) stump and the sub-fifth metatarsal head. Two patients

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Table 1. Patient profiles, wound characteristics and outcomes following collagen matrix application

Case	Age, years	Sex	Initial wound size, cm	Comorbidities	Pre-application wound duration	Contributing factors	Days to full closure	Early wound response	Follow-up outcome
1	54	F	2.0×1.5×0.5	Multiple sclerosis, paraplegia	3 months	Immobility, sensory loss	27	Significant improvement by day 14 (~98% reduction)	Wound remained closed at day 69
2	68	M	1.0×1.5×0.4	Type 2 diabetes, hard-to-heal foot ulcers	~3 years intermittent, 4 months continuous	Neuropathy, tailor's bunion	52	Progressive closure, no complications	Closure stable at day 131
3	60	M	4.5×4.5×1.0	Type 2 diabetes, peripheral neuropathy, dementia	4 weeks	Post-TMA pressure point, sensory loss	41	76% size reduction by day 6	Wound remained closed; amputation avoided

F—female; M—male; TMA—transmetatarsal amputation

underwent surgical offloading procedures (exostectomy or metatarsal head resection) in addition to debridement; one patient received sharp debridement for a deep tunnelling wound.

Complete wound closure was achieved in all three patients following a single application of collagen matrix. Time to closure ranged from 27–52 days. No complications, such as secondary infection, dehiscence, or need for further surgical intervention, were reported. At follow-up evaluations (ranging from 41–131 days after treatment), all wounds remained closed without recurrence.

Fig 1 shows the duration of chronicity before treatment with collagen matrix and time to wound closure following application of a bovine-derived collagen matrix. Pre-treatment wound duration ranged from 28 days (Case 3) to approximately three years (Case 2). Despite the prolonged chronic phase, all three patients achieved complete wound closure within 27–52 days after collagen matrix application. The mirrored timeline illustrates the contrast between prolonged wound chronicity and relatively rapid post-treatment wound closure.

Fig 2 illustrates the percentage of wound area reduction over time in two patients treated with the bovine-derived collagen matrix. Case 3 demonstrated a

Fig 1. Wound duration before and after collagen matrix application

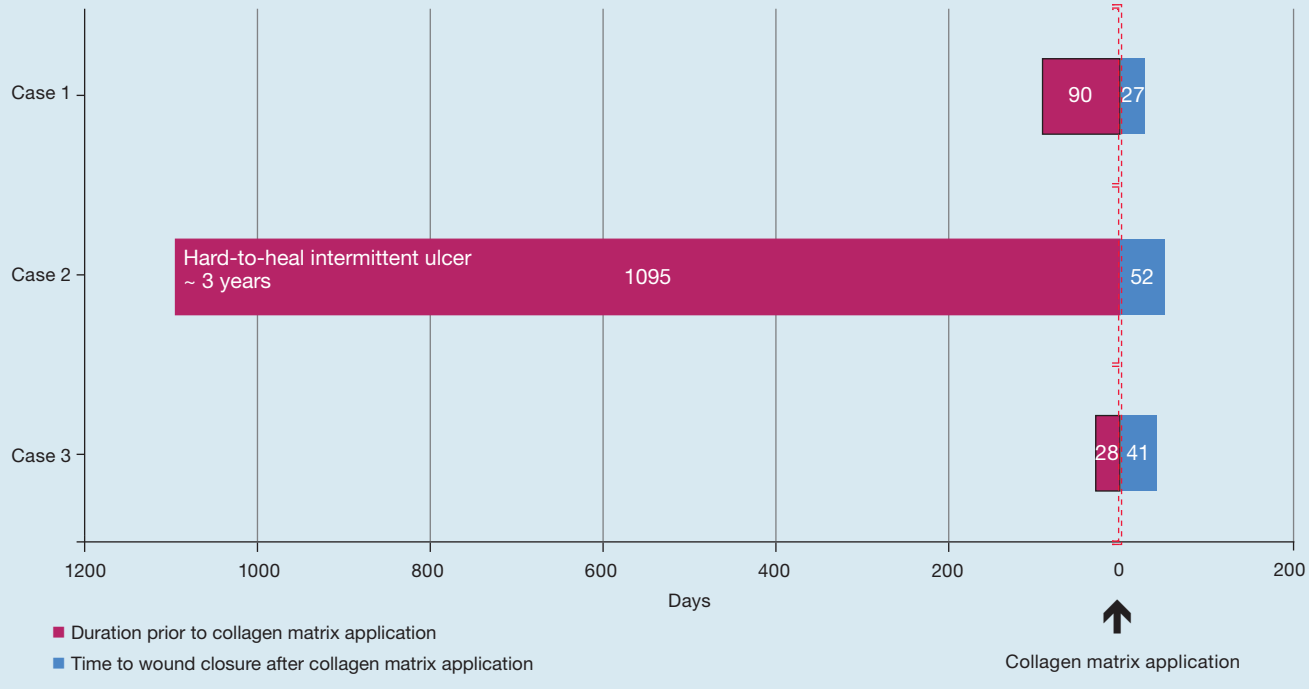

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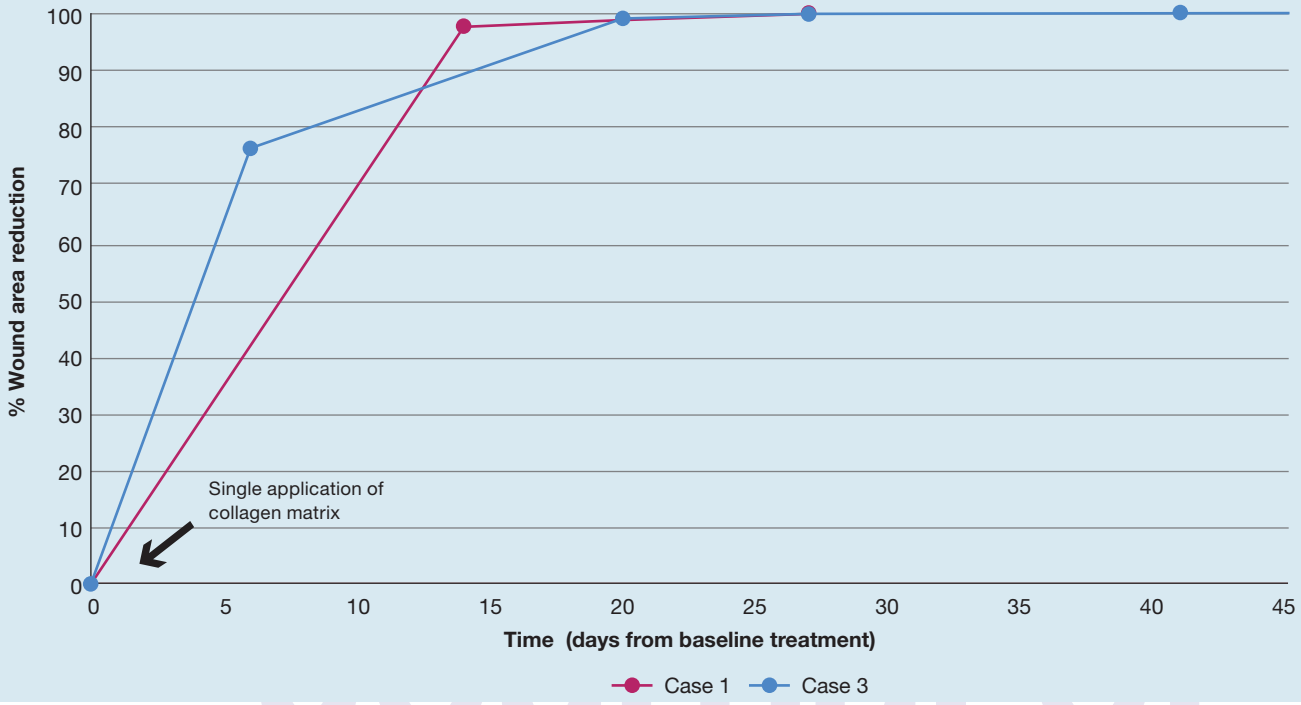
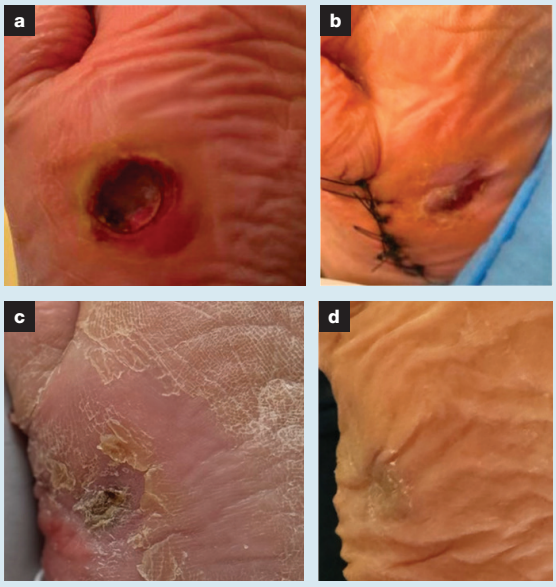
Fig 2. Percentage wound area reduction over time after collagen matrix application. Case 2 was managed with primary closure and wound edge approximation, preventing accurate measurement of wound size during the early closure phase. As a result, this case is not included



76.3% reduction by day 6 and achieved full closure by day 27. Case 1 showed a 97.6% reduction by day 14, progressing to complete closure by day 27. The figure highlights the rapid and substantial wound responses observed following a single collagen matrix application.

Fig 3. Case 1. A 54-year-old female patient with multiple sclerosis and paraplegia presented with a hard-to-heal stage 3 pressure injury on the right foot. The ulcer was located at the sub-fifth metatarsal head. At day 0, when the matrix was applied **(a)**; at day 14 **(b)**; at day 27**(c)**; and at day 69 **(d)**



Case presentations

Case 1

A 54-year-old female patient with MS and paraplegia presented with a hard-to-heal stage 3 PI on the right foot, measuring 2.0×1.5×0.5cm, located at the sub-fifth metatarsal head. The ulcer had persisted for three months despite multiple advanced wound care treatments, including silver alginate, Prisma (Promogran Prisma Matrix; Systagenix, UK), Hydrofera Blue (Hydrofera, LLC., US), and cadexomer iodine, none of which promoted closure. Her impaired mobility due to MS and paraplegia contributed significantly to the ulcer's chronicity and presented challenges to effective treatment.

Given the ulcer's hard-to-heal nature, its location over a pressure-prone bony prominence and the presence of devitalised tissue, the patient underwent fifth metatarsal head resection and surgical debridement. These procedures were performed to remove necrotic tissue and structurally offload the area, thereby eliminating the mechanical pressure and potential osseous involvement that hindered healing. Following the procedure, a single application of dry bovine-derived collagen matrix (500mg, single-use unit) was made to the wound bed to support granulation and re-epithelialisation. The wound was dressed with a

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non-adherent layer, gauze and a Kerlix wrap to maintain a moist environment. The patient was instructed to remain non-weight-bearing in a wheelchair to prevent additional pressure and was temporarily unable to participate in physical therapy for gait training.

By day 14, the wound area had reduced by approximately 97.6%, with complete closure observed by day 27 with a single collagen matrix application. At follow-up on day 69, the wound remained closed with no evidence of recurrence. The patient resumed her normal activities.

Case 2

A 68-year-old male patient presented with a hard-to-heal stage 3 PI measuring 1.0×1.5×0.4cm at the left fifth metatarsal head. His medical history included type 2 diabetes, peripheral neuropathy, a tailor's bunion and bilateral chronic foot ulcerations. The wound had recurred intermittently over the previous three years and had remained continuously open for approximately four months, qualifying it as a hard-to-heal ulcer. This classification was based on its prolonged duration, repeated recurrence, and the presence of comorbid conditions known to impair wound healing. A few weeks before the most recent exacerbation, the patient had undergone a left first metatarsal phalangeal joint fusion.

On initial evaluation, the wound showed necrosis and pressure-related changes. The patient underwent surgical debridement and exostectomy to prepare the wound bed and offload the affected area. Dry bovine-derived collagen matrix (500mg, single-use unit) was placed into the wound bed as a single application. The skin edges were re-approximated and sutured to promote primary closure. The wound was dressed with a non-adherent layer, a 4×4cm gauze pad and a Kerlix wrap. The patient was advised on pressure offloading using a CAM boot and diabetic healing shoe. Regular wound assessments were scheduled to monitor closure.

The wound achieved complete closure within 52 days following a single collagen matrix application, with stable primary closure noted as early as day 3. At follow-up on day 131, the wound remained fully closed, with no evidence of complications or recurrence. Due to surgical approximation and early primary closure, serial wound measurements were not feasible and were therefore not recorded.

Case 3

A 60-year-old male patient with a history of type 2 diabetes, peripheral neuropathy and dementia presented with a hard-to-heal stage 3 PI measuring 4.5×4.5×1.0cm on the plantar lateral aspect of his left TMA stump. The ulcer demonstrated extensive tissue loss with visible subcutaneous involvement and had been open for four weeks with minimal signs of healing. The patient's comorbidities significantly impaired his ability to perform self-care, contributing to the persistence of the wound. He had previously undergone a partial fifth toe amputation and a partial fourth ray amputation due to osteomyelitis, both of which healed without complication. These procedures ultimately led to a left TMA. Following the TMA, pressure redistribution and loss of lateral forefoot support made the plantar lateral aspect of the stump particularly prone to ulceration. This region often becomes a weight-bearing focal point, especially in patients with prior lateral ray loss, due to altered biomechanics, reduced soft tissue padding, and shear forces during transfers or residual ambulation. At six months following the TMA, he developed a PI at the lateral stump, raising concern for the need for a more proximal amputation, which would have significantly impacted his mobility and QoL.

On initial evaluation, the wound exhibited deep tunnelling and necrotic tissue, requiring aggressive debridement. Active bleeding was noted, indicating adequate perfusion and a favourable wound environment. A single-use 500mg unit of dry bovine-derived collagen matrix was applied to the wound bed as a single application, and the wound was dressed with a non-adherent layer. The patient was instructed to remain non-weight-bearing in a wheelchair to offload pressure from the ulcerated area.

By day 6, the wound area had reduced by 76%, with healthy granulation tissue forming and the tunnelling beginning to resolve. Complete closure was achieved by day 41 following a single application of the collagen matrix, preventing the need for further amputation. This notably improved the patient's mobility and overall QoL.

Fig 4. Case 2. A 68-year-old male patient with type 2 diabetes and peripheral neuropathy presented with a hard-to-heal stage 3 pressure injury at the left fifth metatarsal head. At day 0 **(a)**; at day 0, with a single-use unit of dry HELIOGEN (500mg) **(b)**; at day 0, skin edges re-approximated and closed primarily **(c)**; at day 3 **(d)**; and at day 131 **(e)**

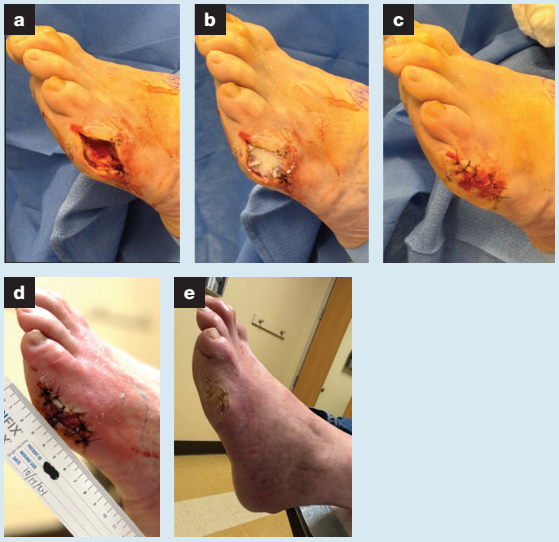

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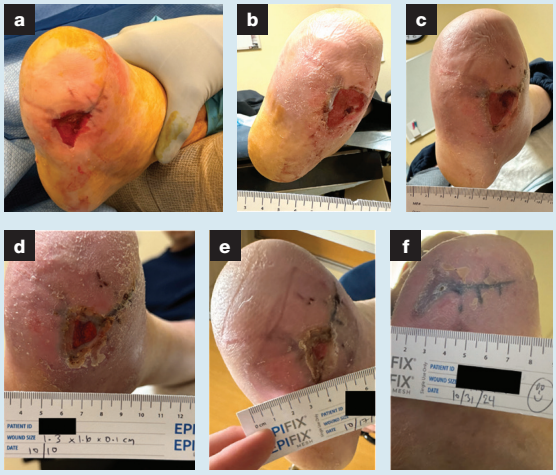
Fig 5. Case 3. A 60-year-old male patient with a history of type 2 diabetes, peripheral neuropathy and dementia presented with a hard-to-heal stage 3 pressure injury on the plantar lateral aspect of his left transmetatarsal amputation stump. At day 0 **(a)**; at day 6 **(b)**; at day 13 **(c)**; at day 20 **(d)**; at day 27**(e)**; and at day 41 **(f)**



Discussion

Hard-to-heal PIs in patients with complex comorbidities remain a persistent challenge in wound management, often requiring prolonged care and carrying a high risk of complications, such as infection, limb loss and diminished QoL.[9–12] This risk is further amplified in higher-stage ulcers, which involve deeper tissue structures and typically demand more aggressive interventions than stage 1 or stage 2 PIs.[1]

The three cases in this series illustrate the potential of a single application of the collagen matrix to facilitate rapid and complete wound closure in medically complicated patients. All ulcers were classified as stage 3, involving full-thickness skin and soft tissue loss with a significant risk of deterioration. Each patient presented with a hard-to-heal PI that was unresponsive to SoC. Importantly, all patients in this series exhibited significant healing impairments due to comorbidities such as MS with paraplegia, type 2 diabetes, peripheral neuropathy and dementia. These conditions are well-documented risk factors for delayed wound closure, associated with impaired circulation, reduced immune response, and limited ability of the patient to adhere to pressure offloading and self-care regimens. Despite these barriers, all wounds achieved complete closure within 27–52 days following a single bovine-derived collagen matrix application, substantially shorter than the duration of chronicity before treatment, which ranged from four weeks to approximately three years. This contrast underscores the potential of collagen matrix in managing high-risk, treatment-refractory PIs. The duration of chronicity prior to treatment with collagen matrix highlights the burden these wounds can impose when left unresolved. Achieving full closure within a markedly shorter timeframe suggests not only clinical efficacy, but also a potential for greater cost-effectiveness. By reducing the need for prolonged care, repeat interventions and complication-related procedures, single-application collagen matrix treatment may help lower healthcare use in high-risk clinical scenarios. This potential was observed consistently across the three cases, despite differences in ulcer location and complexity. Early wound responses were also notable: one wound reduced in area by 98% by day 14, and another by 76% by day 6. In Case 2, where the wound was closed by primary intention, stable closure was observed as early as day 3. These findings highlight not only the effectiveness of the collagen matrix when combined with SoC but also the speed of tissue response in a population where wound closure is typically delayed.

Wounds varied in location, size and depth—from sub-metatarsal head ulcers to complex post-amputation stump ulcers—yet all responded favourably to the same treatment protocol. This consistency suggests broad applicability of the bovine-derived collagen matrix across different anatomical sites and levels of tissue involvement. Additionally, none of the cases required repeat application, indicating a potentially cost-effective approach that minimises patient burden and optimises healthcare resource use. A particularly compelling example is Case 3, in which the collagen matrix application directly contributed to limb preservation as part of the continuum of care. This reinforces the broader implications of timely wound closure: restoring tissue integrity, preserving mobility and independence, and improving overall QoL. These cases also emphasise the importance of comprehensive wound care. Surgical debridement, pressure offloading and appropriate dressing techniques were integral to management. The bovine-derived collagen matrix functioned as an effective adjunct within this multidisciplinary framework, enhancing rather than replacing SoC protocols.

The outcomes observed in this case series are consistent with prior studies demonstrating the clinical benefits of collagen-based matrices in hard-to-heal wound care. Previous RCTs and meta-analyses have reported improved wound closure rates, accelerated time to closure, and reduced the need for repeat interventions when collagen dressings or matrices are used as adjuncts to SoC.[24,25,27,30] However, many of these studies involved multiple applications over extended periods. In contrast, the present series demonstrates that a single application of a bovine-derived collagen matrix, when integrated into a comprehensive treatment protocol, may achieve comparable or superior outcomes in high-risk patients with stage 3 PIs. This suggests a potentially more efficient and resource-conscious therapeutic approach for managing complex wounds.

Limitations

While these results are promising, they are limited by

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Reflective questions

- What patient-specific or wound-related factors may influence responsiveness to bovine-derived collagen matrix in the treatment of hard-to-heal stage 3 pressure injuries (PIs)?
- In what ways can bovine-derived collagen matrices be effectively integrated into comprehensive wound care protocols for patients with significant comorbidities or impaired healing capacity?
- What types of clinical studies are most needed to evaluate long-term outcomes, application frequency and patient selection criteria for collagen matrix use in PI management?

the small sample size and lack of a control group. Further studies, including RCTs, are needed to confirm these findings, determine optimal patient selection criteria, and evaluate long-term outcomes. Nonetheless, the rapid and complete wound closure observed in the medically complex patients in this study suggests that collagen matrix application may offer meaningful therapeutic value in hard-to-heal wound care.

Conclusion

These findings highlight the potential value of bovine-derived collagen matrix as an effective adjunct to established wound care protocols, particularly in high-risk, treatment-refractory cases. The consistency of outcomes across different anatomical locations and patient profiles suggests broad clinical applicability. Moreover, the ability to achieve full closure with a single application may reduce treatment burden, improve compliance and optimise resource use. While further research is needed, this series supports the integration of collagen matrix as a valuable component of multidisciplinary wound care strategies. **JWC**

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