Bioabsorbable Temporizing Matrix (BTM): Not Just for Burns

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ABSTRACT

A skin substitute developed in Australia 2 decades ago for use in acute burns was recently introduced into the United States for the treatment of open wounds. This product has been shown to be very efficacious for coverage of debrided burn wounds. It consists of an inorganic synthetic woven layer that induces cellular ingrowth and deposition of interstitial tissue. It is covered by an attached silicone layer that seals the wound. The product is placed with the woven side directly on the wound. It is fixed in place and optimally covered by a negative pressure dressing for the first 5-10 days. Due to its synthetic composition, it is highly resistant to infection and can stay on the wound for as long as needed. The authors have used this matrix in a wide variety of complex reconstructions in 27 patients, consisting of 10 females and 17 males. Eleven had traumatic wounds of various etiologies (deep burns, crush injuries, Morell-Lavallee lesion, hand injuries, multiple trauma, open fractures, compartment syndromes and soft tissue avulsions). The following wounds were also treated with BTM: pressure ulcers, axillary hidradenitis, scalp wounds, severe facial acne keloidalis, Fournier's gangrene, a diabetic foot ulcer, a chronic venous ulcer, a cutaneous pyoderma gangrenosum, a radiation ulcer with exposed Achilles tendon, a disfiguring scar from an old Dupytrens excision and a non-healing chemotherapy extravasation ulcer. Hand and leg wounds with exposed tendon achieved coverage without tethering. The scalp wounds developed a neodermis and were skin-grafted. A pyoderma gangrenosum patient with excessive slough and uncontrolled bleeding was temporarily immunosuppressed, aggressively debrided and covered with the matrix. Her bleeding resolved. She developed a neodermis, and had reduced symptoms. The Fournier's patient had immediate skin-grafting of his penis and testicles, but the remaining extensive perineal and upper thigh wounds were treated with the matrix and healed without additional skin grafting. A hand patient with a forearm fasciotomy wound was covered with the matrix. As the swelling resolved the size of the defect decreased to the point that the wound was delaminated. The adjacent skin was elevated and used to cover the open area, achieving full closure. There were no complications attributed to the use of the matrix. Several patients healed secondarily with the silicone sheeting gradually peeling off. Seven

patients have received or are awaiting skin grafts to be placed over the neodermis. Although this is an early review of the use of this synthetic matrix in the US, it comes with a positive legacy from Australia. The findings thus far indicate that there is a wide range of applications for this product well beyond burn care. Its safety record, resistance to infection and ease of use facilitate surgery.

INTRODUCTION

NovoSorb Biodegradable Temporizing Matrix® (BTM) (PolyNovo, Carlsbad, CA) is a synthetic skin substitute that consists of wound-facing biodegradable polymer foam bonded to a non-biodegradable transparent sealing membrane. It was initially developed using a variety of biodegradable polyurethanes with an external layer of silicone. This dissolvable synthetic is engineered to dissolve within 3 weeks, disappear completely from the local tissue within 12-18 months, not incite an inflammatory reaction, and support neovascularization and cellular ingrowth. Dr. John Edward Greenwood from the Royal Adelaide Burn Unit did the initial investigative work and later was the first to deploy BTM for clinical use in 2012.[1,2] He recognized the shortcomings of split-thickness skin grafting and was anxious to prevent scar deformities associated with large burn injuries. An ideal skin substitute should be able to resist infection, prevent water loss, withstand shearing forces, lack antigenicity, have a low cost, be widely available, be durable, and be easy to use. The acellular and biodegradable properties of the matrix provide low antigenicity with resistance to infection as there is no food source for bacteria.[3] BTM was developed as a burn dressing and has been used primarily for that purpose. Recently it has been adapted for use in a variety of wounds including pressure ulcers, venous ulcers, necrotizing fasciitis wounds, flap donor sites, and traumatic wounds.[4-11] The first step in using BTM requires thorough debridement of the wound, as for any reconstructive procedure. The BTM is then affixed with sutures or staples end-to-end with the skin with the foam matrix in contact with the wound. Optimally, it should be covered with a nonadherent gauze and stabilized with a negative-pressure dressing or a bolster. The Plastic Surgery Division at Rutgers New Jersey Medical School has used BTM for a wide variety of cases. We reviewed an internal quality assurance report of these patients, and present here the preliminary experience of our group's use of this skin substitute.

METHODS

This report presents the results of a single-center case series involving patients with complex wounds who underwent BTM placement from January 2022 to June 2023. Thirty consecutive patients were treated. Three patients were excluded from this review; one died of sepsis and multiorgan failure unrelated to the BTM, but prior to the time when we could properly evaluate his wounds, and the other 2 eloped from our practice and have not followed-up with us. Since this is a preliminary review, the end-point of a healed wound was not achieved in all patients. Patient demographics as well as type, location, size, and a brief wound history were collected (Table I). No personal health information was collected.

RESULTS

There were 10 female and 17 male patients. Nine male patients had predominantly traumatic wounds of various etiologies including burns, crush injuries, multiple trauma, open fractures, Morel-Lavallee lesion and soft tissue avulsions. Two male patients were treated for pressure ulcers. The remaining males were treated for Fournier's gangrene, facial acne keloidalis, a heel ulcer, factitious ulcers, a sarcoma resection defect of the foot, and scar conditions, respectively. The female patients included 3 with axillary hidradenitis, one with a below-the-knee (BKA) prosthesis-related popliteal ulcer, severe bilateral lower-extremity pyoderma gangrenosum with slough and hemorrhage, one radiation-related ulcer with an exposed Achilles tendon, a massive scalp squamous carcinoma, a venous leg ulcer, a nonhealing chemotherapy extravasation wound, and a hand contracture from an old Dupytrens excision. The patients were all aged 12-84 years, and the wound sizes varied from 24 cm^2 to 2055 cm^2.

Two patients had failed split-thickness skin grafts (STSG) after BTM, but maintained granulating wounds. A significant cause of graft failure in these 2 patients was patient behavioral issues. All of the patients listed as "secondary healing" are not planned to have skin grafting. The wounds contract rapidly and epithelialize from the periphery under the outer seal. All the wounds that were delaminated had a completely granulating surface except for the pyoderma patient.

DISCUSSION

BTM was developed for use in burn patients. The synthetic cellular and biodegradable properties of the matrix remove the risk of antigenicity, are not inflammatory, and provide resistance to infection since the matrix is not a food source for bacteria. A pivotal quality of BTM compared to STSG is that it can be placed over exposed tendon and bone, which is often a problem faced by plastic and reconstructive surgeons when managing complex wounds. Another favorable attribute is that restoration of the dermal layer of the wound results in a more uniform contour as well as an acceptable STSG base.[7] A 12-month follow-up study has demonstrated good cosmetic outcomes and near-normal flexion at the shoulder, knee, and ankle with low levels of itch and pain.[12] Recent publications have broadened the scope of use of this product to include necrotizing fasciitis wounds, diabetic foot wounds, scalp avulsions, and head and neck surgical defects. There is a need for a safe, inexpensive, and effective skin substitute for use in trauma, oncologic, and chronic wound patients.[13]

This paper is intended to demonstrate how BTM can be used outside of the burn population. While this study presents a preliminary review, all the patients achieved either a healed wound or a fully granulated wound with a pseudo-neodermis, or were skin-grafted. It was hard to determine the time to graft integration in our service since the patient appointments were generally 1-2 weeks apart and some appointments were missed. However, integration was noticed after 13 days and by 33 days. Punch biopsy evaluations by PolyNovo (Carlsbad, CA) have demonstrated cellular activity throughout the matrix by day

Table I
Data summary

Patient		Condition	Treatment	Result
sex	age(y)			
M	62	bilateral hand burns 85 cm^2	amputation of right hand, flaps, BTM	STSG healed
M	37	forearm fasciotomy 40 cm^2	BTM	delamination and primary closure
M	43	burn scar revision elbow and hand 128 cm^2	BTM	90 cm^2 STSG 100% take
M	83	scalp pressure ulcer stage 4 143 cm^2	burred calvarium, BTM	STSG pending
F	67	hand contracture 60cm^2	release contracture BTM	STSG 100% healed
F	62	chronic venous ankle wound 25 cm^2	2 debridements, BTM	secondary healing
M	23	Traumatic wound with bone and muscle 250 cm^2	3 debridements, Ortho fixation, BTM	STSG healed
M	12	Traumatic wound of ankle with bone and tendon exposed, 75 cm^2	debridement and BTM	secondary healing
M	39	Old ankle fracture with exposed hardware and chronic osteo, 26 cm^2	debrided multiple times, BTM, failed STSG	lost to follow up
M	39	Crush injury of leg, multiple fractures, skin loss 800 cm^2	Multiple debridements , orthopedic fracture fixations, and BTM	STSG healed
F	66	Squamous carcinoma of scalp 350 cm^2	Radical excision, dural repair, cranial defect, latissimus free flap BTM, STSG	STSG 90% healed
M	38	Scarred tendons, nerve, skin slough post crush injury 21 cm^2	Tenolysis, neurolysis, excision of scar, BTM	secondary healing
M	33	bilateral facial acne keloidalis 175 cm^2	Excison and BTM	STSG pending
F	44	BKA prosthesis related ulcer 66 cm^2	Excision and BTM	secondary healing
M	39	Traumatic avulsion ankle with exposed tendon 400 cm^2	Debridement and BTM	Failed STSG
F	84	Radiation-related ulcer with exposed Achilles tendon	Debridement and BTM	secondary healing
F	24	Pyoderma gangrenosum with slough and hemorrhage 2055 cm^2	Immunosuppression,surgical debridement, BTM	secondary healing
M	49	Fournier's gangrene 300 cm^2	Multiple debridements, STSG penis and testicles, BTM	Healed
M	39	Iscial pressure ulcer widely exposed bone 52 cm^2	Debridement BTM, delayed STSG at 6 mo. FU 3 mo later	90% healed
M	49	tetraplegia with ischial and sacral stage 4 pressure ulcers 24 cm^2	ulcer excision BTM	secondary healing
F	52	non healing chemotherapy extravasation dorsal hand wound 33cm^2	excision, BTM	secondary healing
F	58	Hidradenitis axilla 350 cm^2	excsion, BTM	secondary healing
F	30	Hidradennitis axilla 560 cm^2	excision, BTM	secondary healing
M	40	heel ulcer 33 cm^2	excision, BTM	secondary healing
F	43	hidradenitis axilla 168 cm^2	excision, BTM	secondary healing
M	59	bilateral upper leg anterior ulcers -drug related 480cm^2	excision BTM	STSG pending
M	32	Clear cell Chondrosarcoma of foot 64 cm^2	exposed plantar fascia, medial and lateral plantar bundles, BTM, STSG	100% STSG take

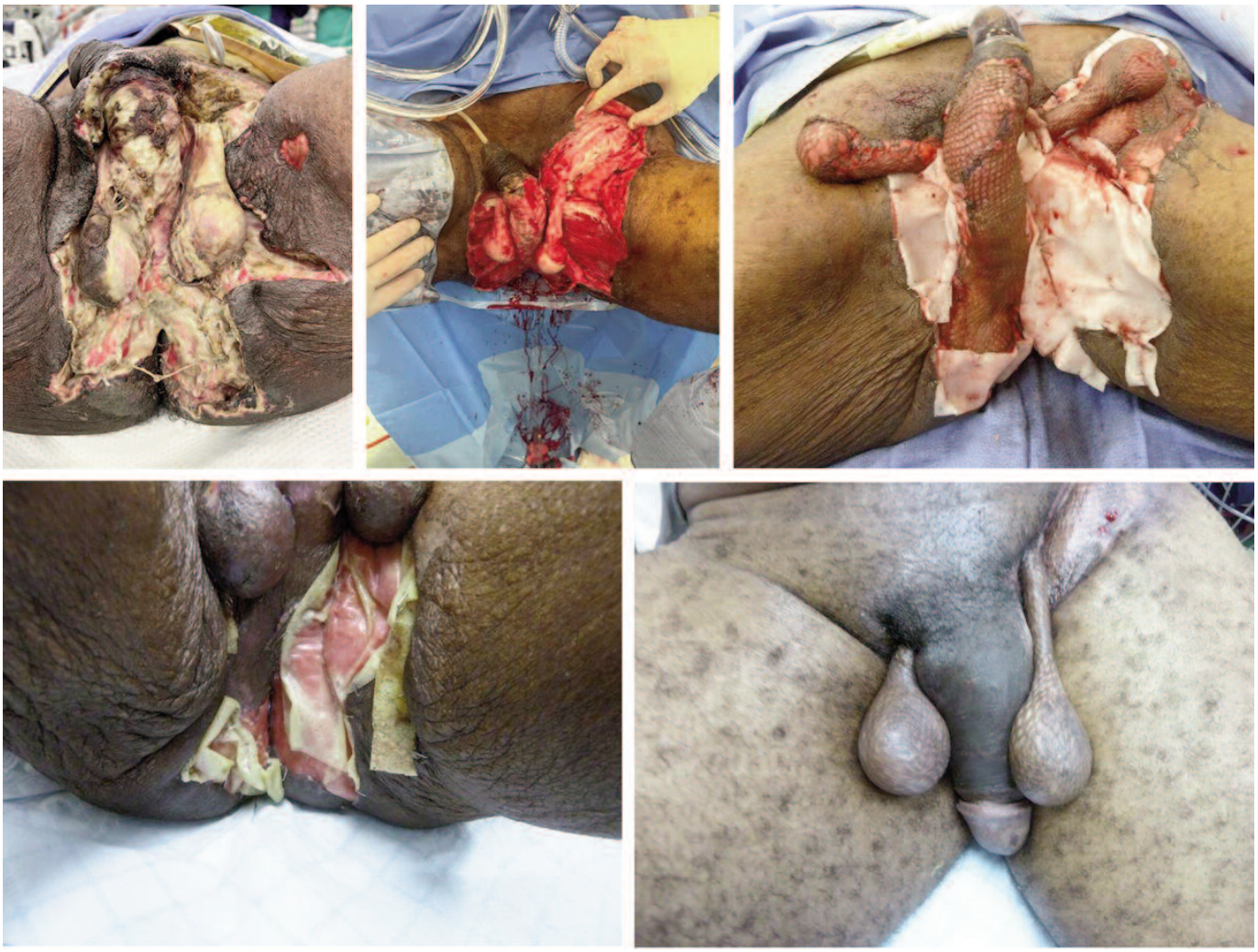

Figure 1. (a) Extent of the patient's Fournier's Gangrene at the time of presentation. (b) After multiple debridements, the wound was prepared for reconstruction. (c) BTM (413 cm2) was fixed in place and bolstered with a negative-pressure dressing. (d) The upper inner-thigh wounds contacted to fill the defect. The BTM was trimmed away as it loosened. (e) Healed wound.

15 and significant dermal integration by day 33.[3] Some patients who showed premature delamination still went on to granulate and even to heal. Presumably, some of the mesh remained in the wound and this was sufficient to promote neovascularization. No complications occurred due to the use of BTM.

There are lessons to be learned from many of our patient experiences. The patient with **pyoderma gangrenosum** had very aggressive wounds that were covered with a thick layer of slough and severe pain. She started hemorrhaging, which required multiple transfusions. We applied temporary immunosuppression with high-dose steroids, operatively debrided her legs and covered the ulcers with 2055 cm^2 of BTM. Her hemorrhaging stopped and has not recurred. One of the legs is almost healed, the other has about 50% granulations and fibrinous debris, but no slough build-up. Her pain is markedly reduced. In this case, BTM helped reduce pain and maintain a stable wound.

The patient with **Fournier's Gangrene** has type 2 diabetes mellitus and takes empagliflozin. He developed florid gangrene requiring multiple debridements (Figs. 1a,b), and then skin grafting of the penile shaft and testicles. BTM was placed on a 413 cm^2 wound on the upper thigh and perineal wounds (Fig. 1c). He healed without further skin grafting and with minimal scarring. The silicone backing was trimmed away as the wounds contracted until they were almost healed (Fig. 1d). It was then removed, and he healed completely without requiring a STSG (Fig. 1e). BTM does not require skin grafting to achieve healing in some patients. The plan now is to wait for about 1 year, and then create a new scrotum and remove the STSG.

Another patient had BTM placed over a large nonhealing area of **exposed bone in a long-standing stage 4 ischial ulcer**. He removed the VAC and BTM within a few days of the surgery, missed his post-operative appointment and came in on the second week post op with the BTM still attached to the wound periphery in one area. The VAC was gone. The BTM looked like 80% of the polyurethane mesh was missing from the silicone backing. Surprisingly, his exposed bone was covered with a granulating base. He subsequently did not return for a visit for 3 months. At that time he was admitted by the Hospitalist from the ED and had a new ischial ulcer on the contralateral side. The ulcer that had been previously treated with BTM was >90 % healed with a thin margin of granulation tissue measuring 1 x 5 cm. BTM is durable and resilient in the face of challenges from the wound and the patient.

The **forearm fasciotomy** patient had BTM placed acutely on the fasciotomy site. It decreased in size sufficiently to delaminate the graft and close the skin

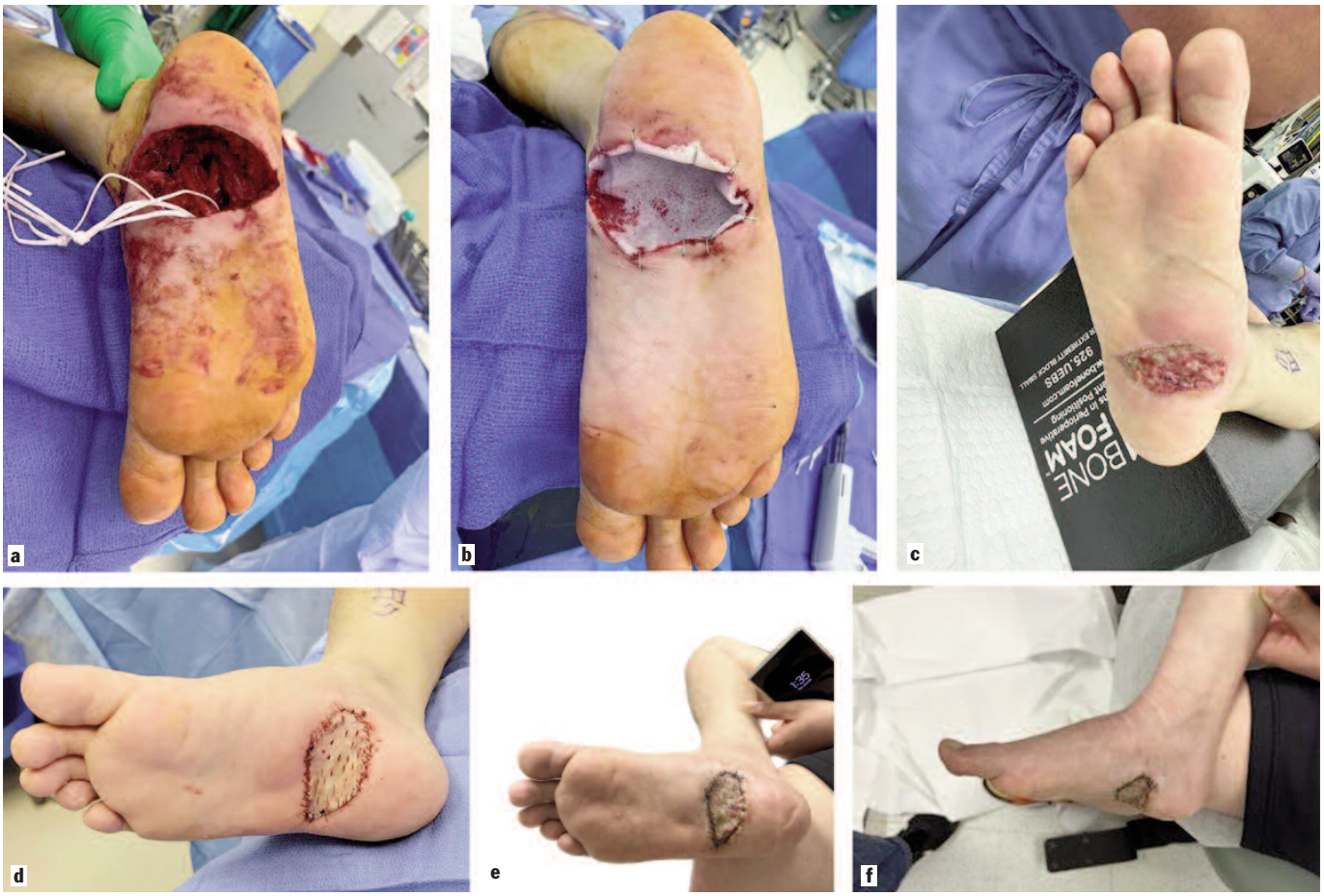

Figure 2. (a) Oncologic resection of a chondrosarcoma of the foot created a deep defect with exposed neurovascular bundles. (b) BTM (64cm2) was fixed in place and bolstered with a negative-pressure dressing. (c) The defect filled in and the outer membrane was delaminated. (d) A STSG was performed. (e) Plantar view of the skin graft. Note the complete graft take and restoration of the normal contour. (f) Lateral view of the skin-grafted wound. Again, note the complete graft take and the normal contour.

primarily. While closure of fasciotomy wounds is usually much more difficult than it appears to be, it was easy with BTM.

The patient with a **radiation ulcer** on her leg experienced severe pain and had a largely necrotic Achilles tendon and adjacent open wound. Previous standard-of-care dressings did not improve her wound. It was operatively debrided and covered with 132 cm^2 of BTM. The patient's pain improved immediately. Since she was very fragile, the family did not want further surgery. At 8 weeks, her sealing membrane was largely detached and was removed completely. Her tendon and the surrounding wound were covered with a red neodermis. The patient was subsequently placed in Hospice due to metastatic disease. BTM can be effective over exposed tendon and other relatively avascular structures. It can also be effective in generating neodermis in a radiation-related wound.

The patient who had a **crush injury to his wrist** showed lacerations of multiple tendons and the ulnar nerve. The tendons were repaired and the nerve required an interposition graft. The overlying skin healed, but developed a thick scar that tethered the underlying structures. This was excised along with a tenolysis and neurolysis. BTM was placed. It delaminated 6 weeks after surgery revealing neodermis. All the structures were freely mobile. BTM did not tether underlying structures in this patient. It also was effective in covering exposed repaired tendon.

The patient with the **heel ulcer** had a superficial wide debridement. In the central portion of the wound a 1 cm-diameter plug of diseased tissue was removed with exposed bone at the base. The bone was biopsied. The hole was filled with BTM matrix that was removed from an extra portion of the bilaminar graft. A bilaminar piece was then placed over the entire wound. It may be possible to level off an irregular wound with extra matrix placed into shallow defect areas.

A 32-year-old male patient with a **chondrosarcoma** of his right foot underwent oncologic resection. Plantar fascia and the medial and lateral plantar neurovascular bundles were in the field (Fig. 2a). The full contour of the wound was covered with 64 cm^2 of BTM (Fig. 2b). The wound filled in completely to a normal contour (Fig. 2c). It was then delaminated and a STSG was applied 2 months after the initial surgery (Fig. 2d). The graft take was 100% with a fully restored and normal contour (Fig. 2e,f).

BTM shows a remarkable tendency to fill in contour defects of considerable size A 66-year-old female patient showed **squamous cell carcinoma** of the skin of her scalp (Stage 4) with erosion through her skull, meninges and brain. It also involved the ear, lateral face, and neck. After radical resection of her external ear and excision of skull, meninges, and brain, the skull defect was closed with an acellular dermal matrix. A latissimus myocutaneous free flap was then used over the entire wound. The exposed muscle was closed at that time with 350cm^2 of BTM. This allowed for immediate closure of this very large wound with the expectation of maintaining more

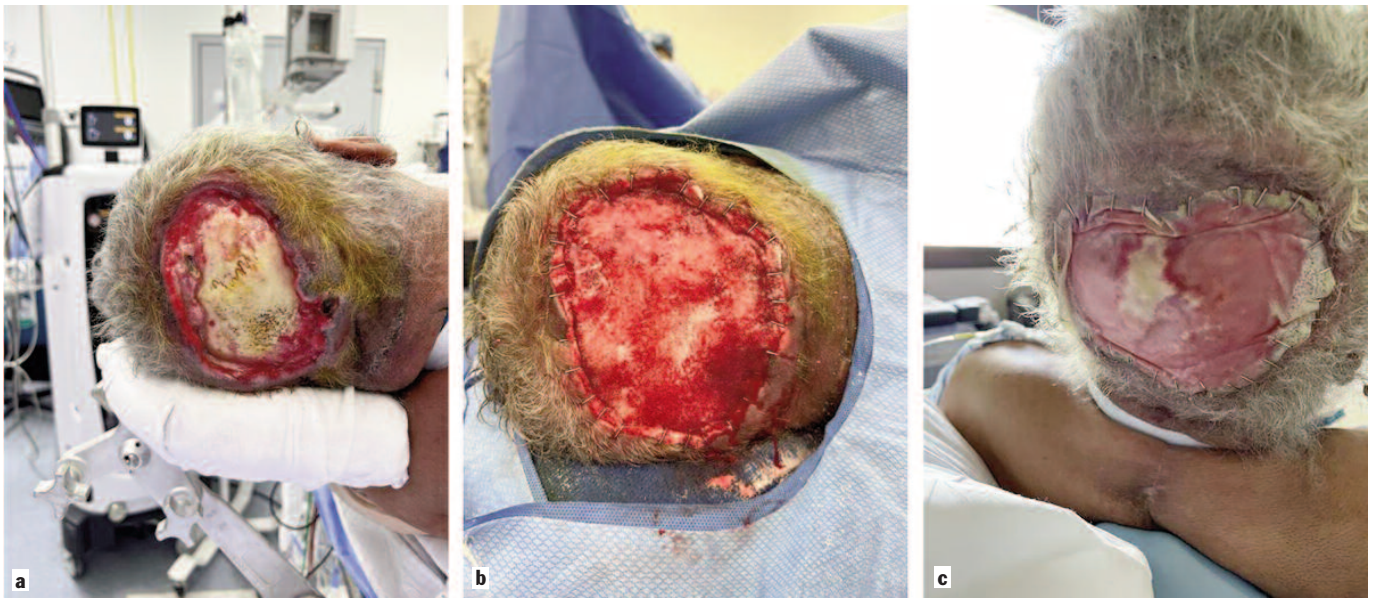

Figure 3. (a) The patient had a stage 4 pressure ulcer of the scalp. This photo shows the soft tissue debridement. (b) The outer table of skull was burred down to diploe and BTM (143) fixed in place and bolstered. (c) The red areas of BTM are fully integrated and vascularized 3 months after the surgery. The pale central area demonstrates the persisting BTM that has not yet integrated with the underlying tissue.

flexible skin adjoining the face and neck once it was all healed.[14]

BTM can stay on a wound for as long as needed, since it is synthetic. An 88-year-old man suffered a severe brain injury. During his recovery, he acquired a **stage 4 pressure ulcer on his scalp**. This was excised down to the skull. The outer cortex was burred down to the diploe. BTM was placed on this defect of 143 cm^2 (Fig. 3). In Figure 3c, the BTM had been in place with the sealing layer intact for 3 months at that time. A small portion of the skull, which appears as a pale spot, is not yet integrated with the matrix. The rest of the skull appears to be vascularized. Once it is fully integrated and vascularized, the wound will be delaminated and skin-grafted.

Biodegradable Temporizing Matrix is a relatively new skin-substitute product; human trials began in 2012. It was initially developed by Dr. John Edward Greenwood from Royal Adelaide Hospital to aid in the management of complex and large burn wounds, and has since been used in a variety of wounds. Several case series have been published recounting authors' experience using BTM in the management of other types of complex wounds.[4-11] This case series describes our experience with BTM ,highlighting the versatility and reliability of using BTM in complex wounds in a challenging patient population.

CONCLUSION

BTM was initially developed to treat burn patients, and it has since been applied to other types of complex wounds. Early results suggest that it is resistant to infection, highly effective for generating neodermis even over avascular structures, can heal a wound secondarily in selected patients, and can fill-in significant contour deformities. In addition, the neodermis can be successfully skin-grafted. This series of patients reinforces the findings reported by other plastic surgeons that BTM is highly reliable and versatile while being low risk and low cost. STI

AUTHORS' DISCLOSURES

MG has received grant support from Biolab Sciences (Scottsdale, AZ) and is a member of the Speakers' Bureau for Organogenesis (Canton, MA). The other authors declare that there are no conflicts of interest.

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