



Case Series

Biodegradable Temporising Matrix: The Rising Star in Synthetic Skin Substitutes for the Hand?

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Abstract

Introduction: Treatment of skin defects in the hand after severe trauma, infections or burns can be challenging. The use of Biodegradable Temporising Matrix may serve as a new soft tissue cover, if skin grafts alone do not heal and flaps are not an option. With the BTM technique a soft tissue defect is closed with a non-biodegradable layer that providing a better barrier against bacteria.

Method: Between December 2021 and December 2022, 27 patients were treated with BTM. In 20 cases the soft tissue defect was caused by a severe trauma. In four patients, there was a skin defect after an infection and in one case each, it was caused by an epitheloid sarcoma, by Dupuytren's disease and MDA5 Dermatomyositis. Following debridement, BTM was applied to the wound. After the granulation tissue has fully integrated into the BTM layer, the sealing membrane is removed and a split-thickness skin graft was applied to the vascularized layer.

Results: The BTM was applied in 9 cases on exposed extensor tendons, in 9 cases on muscle or soft tissue, in 5 cases on bone, in 2 cases on the neurovascular bundle and in 1 case each on exposed flexor tendon and nerve transfer. One infection with enterobacter cloacae was observed after BTM application. The split-thickness graft was well integrated after five days.

Conclusion: The use of BTM is an alternative option with good healing potential, especially in multimorbid patients, who do not qualify for a vascularized flap and who have reduced mobility requirements.

Keywords: BTM; Skin Defect; Split Thickness Skin Graft; Synthetic Skin Substitute

Introduction

Several treatment options are known for skin defects on the hand or forearm depending on exposed structures and area. Therefore, the use of split- or full thickness skin grafts, pedicled (rotation or transposition flaps with or without skin) or free flaps are sufficiently described. Also, the use of artificial dermal templates plays a role in wound closure after injury. However, defects after severe trauma, infections, burns or excisional biopsies of a tumor may be challenging, especially in multimorbid patients, with exposed bone, tendons and nerves. NovoSorb®, Biodegradable Temporizing Matrix (BTM, NovoSorb®, Polymedics, Woodstock,

United States), is a synthetic device with a polyurethane bilayer matrix. According to the manufacturer, BTM is robust in the presence of infection, minimize scarring and contracture, is easy to apply and serves as a cost-effective alternative to biologics [1]. Several studies have determined the safety and ability to provide permanent wound closure when combined with a split thickness skin graft in a two-stage procedure in pigs, mice and humans [2-6]. This study was designed to assess wound closure especially in finger, hand and forearm injuries with exposed structures that otherwise require a flap. The aim was also to analyze the range of motion and therefore the gliding behavior of the tendons, which is essential in hand function. In addition, we analyzed the various indications and suitability for covering defects with BTM.

Material and Methods

BTM is described as a bilayer matrix with a sealing membrane and the NovoSorb® matrix. The non-biodegradable sealing membrane limits the loss of moisture while providing a barrier against bacteria. The bioabsorbable matrix allows a cellular infiltration whereby the dermis regenerated within the matrix [1]. Integration of BTM proceeds in phases and after removal of the sealing membrane the surgeon has the choice between a closure by secondary intention or a split-thickness skin graft. In this study, the following procedure was used: after initial debridement, BTM was applied to the wound. A cellular migration into the matrix leads to new blood vessel formation and production of collagen. After the granulation tissue has formed and fully visibly integrated into the BTM layer, the sealing membrane is removed and a new, vascularized dermal layer emerges. An unmeshed split-thickness skin graft was then harvested from the thigh or inner side of the upper arm and added to the vascularized layer followed by a vacuum-therapy or a tie-over dressing for five days. During that period, the hand was immobilized in a splint to protect wound healing.

Results

Between December 2021 and December 2022, 27 patients were treated with BTM. 16 patients were male with a median age of 55 years (range 12-77 years), while 11 patients were female with a median age of 45 years (range 18-77 years). In 20 cases, the soft tissue defect was caused by a severe trauma. In four patients, there was a skin defect because of an infection. In one case each, an epitheloid sarcoma, Dupuytren's disease or a MDA5 Dermatomyositis caused a skin defect. The dorsum of a finger was affected in 13 cases and the dorsum of the hand in five cases. Four patients suffered from an amputation of one finger (Level of amputation: Zone I and II according to Tamai [7]). One patient each demonstrated a substantial defect at the forearm, at the thenar respectively at the palm. The size of the skin defect ranged from 1 cm² to 200 cm². In four cases the final wound closure was initiated by secondary intention and in one case, the BTM was used in a double layer of the matrix height to rebuild the finger pulp. The BTM was applied in nine cases on exposed extensor tendons (see Figure 1 and Figure 2). Furthermore, it was used in nine cases to cover muscle or soft tissue, in five cases to cover bone, in two cases to cover the neurovascular bundle and on one patient each to cover a flexor tendon and nerve transfer (see Figure 3). On average, the duration between covering the soft tissue defect with BTM and the application of a split-thickness skin graft was 36 days (range 21-111). The take rate for the split-thickness grafts was 96% (Table 1).



Figure 1: Example for BTM covering extensor tendon reconstruction.

- a) 65 years old patient with skin defect (6x2cm), extensor tendon defect und nail bed defect caused by milling machine injury.
- b) Reconstruction of the extensor tendon with palmaris longus tendon graft.
- c) Application of BTM (6x2cm) over the tendon graft.
- d) Granulation tissue after removal of the sealing membrane.
- e) Unmeshed split thickness graft with drainage holes.
- f) Situation four weeks after split thickness skin-grafting.



Figure 2: Example for BTM covering branches of the superficial radial nerve and tendons of first extensor compartment.

- a) 78 years old patient with exposed branches of the superficial radial nerve and first extensor compartment including a 25x7cm soft tissue defect caused by a fall.
- b) Application of 25x5 cm BTM.
- c) 30 days after BTM application.
- d) 5 days after split thickness skin-grafting.

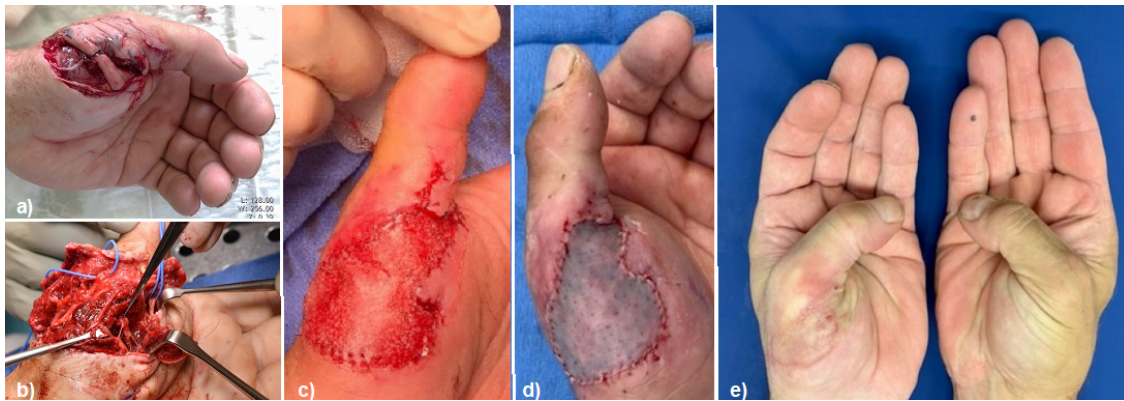


Figure 3: Example for BTM covering nerve transfer at the left thumb.

- a) 45 years old patient with defect of the radio-palmar nerve of the left thumb caused by dog bite.
- b) Sensitive end-to-end nerve transfer of the radio-dorsal to the radio-palmar digital nerve of the thumb.
- c) After BTM Application (size 7x5 cm).
- d) 24 days after BTM.
- e) 44 days after split thickness skin-grafting.

In one case an intermetacarpal island flap was required to reach soft tissue reconstruction (Figure 5) after an enterobacter cloacae infection and already performed BTM application. All other defects healed with BTM and split thickness skin graft (25x) or secondary intention (1x). There were four soft tissue defects that could be successfully covered with BTM despite a known wound infection with pan-sensitive and penicillin-resistant staphylococcus aureus, group B beta hemolytic streptococcus and multiresistant enterobacter cloacae bacteria (Table 1). The average active Range Of Motion (ROM) at least three months after the application of the split thickness graft was analyzed for the fingers and separate for the thumb, (see Tables 2,3). The gliding capacity depended not only on the coverage with BTM, but also on the accompanying injuries.

<i>Location</i>	<i>n</i>	<i>Gender: f: female m: male</i>	<i>Age (median in years)</i>	<i>Cause</i>	<i>Mainly exposed structures</i>	<i>Size of defect (cm²)</i>	<i>Median in days from BTM to graft application</i>
Dorsum of finger	13	f: 6 m: 7	44 (23-77)	Trauma: 10 Infection: 2 Epitheloid sarcoma: 1	Extensor tendons Soft tissue Bone	1-7	37 (21-61)
Dorsum of hand	5	f: 1 m: 4	55 (12-72)	Trauma: 3 Infection: 1 MDA5 Dermatomyositis: 1	Extensor tendons Soft tissue	7-14	45 (18-111)
Finger amputation 3x Level I 1x Level II	4	f: 2 m: 2	50 (25-69)	Severe trauma: 4	Neurovascular bundle Bone	1-5	43 (27-56)
Forearm (dorso- radial)	3	f: 2 m: 1	75 (72-77)	Trauma: 2 Infection: 1	Extensor/Flexor tendons Muscle Soft Tissue	15- 200	22 (21-22)
Thenar (radiopalmar)	1	f: 0 m: 1	47	Trauma (dog bite)	Nerve Transfer Muscle	12	24
Palm	1	f: 0 m: 1	68	Dupuytren's disease	Muscle Soft Tissue	2	0 (Healing by secondary intention)
TOTAL	27	f: 11 m: 16	51 (12-77)			1 - 200	36 (21-111)

Table 1: Study population and statistics.

Fingers	Flexion/Extension
Metacarpophalangeal Joint (MCP)	73-7-0°
Proximal Interphalangeal Joint (PIP)	75-5-0°
Distal Interphalangeal Joint (DIP)	48-4-0°

Table 2: ROM for fingers at least three months after surgery.

Thumbs	Flexion/Extension
Metacarpophalangeal Joint (MCP)	30-0-0°
Interphalangeal Joint (PIP)	27-0-0°
Opposition (Kapandji)	8/10

Table 3: ROM for thumbs at least three months after surgery.

Histological Assessment: The histological assessment of one reference case showed a pronounced scarring fibrosis and a foreign body giant cell reaction. 72 days after the split thickness skin graft was applied, the actual polymer could not be detected but still focal optically empty cavities were identified, perhaps indicating residual portions of the polymer.

Complications: The soft tissue cover over the bony stump after a finger amputation (Tamai Level II) was found to be insufficient at 8 weeks in one patient after split thickness skin-graft. The vulnerability lasted up to five months and then completely regressed. After the fifth month, the patient was able to perform heavy labor without coverage of the stump with a dressing anymore (Figure 4).



Figure 4: Vulnerable bony stump palmar after an IV. Finger amputation (Tamai level II) 8 weeks after skin-grafting. View from palmar (a), lateral (b) and dorsal (c).

One patient suffered from a milling machine injury of the dorsal index finger with a defect of the extensor tendon. A reconstruction with a palmaris longus tendon graft and debriding was performed. The skin defect was covered with a 6x2cm BTM and an empirical oral antibiotic therapy was started (Amoxicillin and clavulanic acid). Penicillin resistant enterobacter cloacae bacteria could be detected from the initial injury and the empirical oral antibiotic therapy was switched to targeted therapy. 47 days after surgery and BTM application the finger was red, swollen and overheated with pus oozing out, see Figure 5. Another debridement was carried out with renewed evidence of enterobacter cloacae bacteria. The definitive soft tissue covering was carried out with a pedicled intermetacarpal flap.



Figure 5: Exemplary infection after BTM application.

- a) Initial trauma with reconstruction of the extensor tendon with palmaris longus tendon graft and coverage with BTM.
- b) BTM coverage 15 days post surgery
- c) Enterobacter cloacae infection 47 days after BTM application
- d) Final result after covery with a intermetacarpal flap.

Discussion

The use of BTM over exposed tendons, nerves, vessels and bones in the hand and forearm with split-thickness skin-grafting or healing by secondary intention demonstrated to be successful in 26 of 27 cases. The application is easy and does not require much previous experience, which is an important aspect from a clinical standpoint [8]. Additionally, the BTM matrix was resistant to tearing and shearing, therefore postoperative immobilization is not essential, except in combined or complex injuries. It was also possible to perform surgery under local anesthesia in certain cases. Some experience is required to recognize the best moment in time to judge the amount of granulation tissue to apply a skin-graft as the secondary procedure. Typically, the change of color from initially white to an orange/reddish color, sometimes in combination with light loosening of the sealing membrane indicates a suitable time for skin-grafting. A delay of skin-grafting results in an epithelialization from the edges of the wound, as aimed by healing via secondary intention. The lack of experience of the team explains the initially longer duration of 111 days from BTM application to skin grafting, which was significantly reduced over time (range 21-111 days). In this study, it was generally found, the older the patient the longer the duration until there was enough granulation tissue present to proceed with skin-grafting. This correlation was not observed in relation to the severity of the injury. In literature, a consistent split-thickness skin-graft take rate of 70 to 90% has been reported for a variety of recipient wound beds [9].

Therefore, the skin-graft take rate of 96% in this study is considered above average and indicates a high reliability of the applied BTM method. Moreover, some wound contraction was present in the cohort; This is in line with similar studies in literature [2], some studies report wound contractions especially in animal models [10]. A tendency to wound shrinkage over time was mainly seen in larger wound areas within the applied unmeshed split-skin graft. To our knowledge the use of BTM in infected wounds has not been reported in literature except from our experience of 4 cases and an additional oral presentation at FESSH 2023 in Rimini (C. Brennan et al: "A-0907 Biodegradable Temporising Matrix (BTM), a viable alternative to flaps for the reconstruction of complex upper limb defects: A case series). There is an advantage to potentially cover soft tissue defects with bacterial contamination especially in high-risk patients with immunosuppression. However, larger future studies are needed. Another purpose of this study was the analysis of the gliding capacity of the reconstructed soft tissue. Bain et al. detected the functional range of motion of the finger joints needed

to perform activities of daily living [11]. Accordingly, the required functional range of motion for the MCP-joint was 19-71° and for the PIP joint 23-87°. In this study, the average movement value for the MCP joint was 73°, which is 2° above the required values, and 75° for the PIP joint, which is exactly within the specified range. From a general hand surgical point of view, the above-described average range of motion (MCP - 73°, PIP - 75°) is not satisfactory. However, these results require a more detailed analysis of the patient population. Many patients had multiple injuries, which not only included soft-tissue injuries but furthermore bony, tendon and/or nerve-vessel injuries up to amputation. The different age groups and different intensity of damage limited the comparability. In a young patient adhesions were found especially around the area of the BTM application. These adhesions could be solved by a single surgical intervention during plate removal with tenolysis. Perdita et al. described a penetration of endothelial CD31 positive cells into the BTM with migrating from the graft boundary and from subcutaneous tissue up into the lower regions of the matrix [2]. However, in order to use this as a possible explanation for adhesion, more studies are required. Further complications included an increased vulnerability and longer healing time over bone stumps. However, after five months of the healing period, adequate soft tissue stability was achieved. In cases of insufficient bone cover, doubling of the BTM layer is possible: after a first granulation phase of 26 days, a second layer of BTM was applied. With this approach no vulnerability over the bone stumps was identified in this group of patients. Usually, the donor side morbidity of the split-thickness skin graft is minimal and contains pigmentation, pruritus, infection, hypertrophic scarring [12,13]. None of these morbidities were found in this study. The application of BTM in combination with unmeshed split thickness skin-graft results in a satisfactory appearance probably superior than a bulky flap.

Conclusion

The application of BTM combined with a split thickness skin graft in a 2-stage procedure shows good healing potential without requiring extensive experience or skills of the surgeon. Soft tissue defects over exposed tendons, bones and nerves can be managed. The appearance and the functional outcome after healing of the BTM and split thickness skin grafts are satisfying. The method shall preferably be used in multimorbid patients, who do not qualify for a vascularized pedicled or free flaps and who have reduced mobility demands. Furthermore, it is possible to apply BTM in infected wounds. However, future studies are required to prove the quality of healing in infected wounds as well as the development of a gliding layer over exposed tendons.

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