Received: 22 January 2021 | Revised: 22 February 2021 | Accepted: 1 March 2021
DOI: 10.1002/ccr3.4676

CASE REPORT

Clinical Case Reports Open Access WILEY

Salvage of a mangled limb with Matriderm® augmented split-skin grafting and maggot biodebridement

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Funding information
No funding was received for this case report

Abstract
Salvage of a mangled limb can be a long and strenuous way, but it is feasible even with rather simple techniques such as augmented split-skin grafting and maggot biodebridement.

KEYWORDS
bio debridement, Mangled limb, Matriderm®, salvage versus amputation, skin grafting

1 | INTRODUCTION

We present a case of a young woman with a mangled leg that could be salvaged with a combination of negative pressure wound therapy, Matriderm® augmented split-skin grafting, and maggot biodebridement. The aim of this case report is to outline alternative treatment options in severe soft tissue injuries.

The management of complex full-thickness soft tissue injuries poses a great challenge to every surgeon. In many cases, the defects will only heal with compromised functionality and aesthetics.[1] In cases where primary closure is not feasible, more complex procedures such as split-skin grafts or even flap surgery might be required. A well-known disadvantage of split-skin grafting alone is the often insufficient underlying dermal tissue leading to compromised functionality, mechanics, and cosmetics.[2-6] Therefore, dermal substitutes functioning as a matrix replacing the subcutaneous tissue have become more frequently used in those kinds of defects with beneficial results for the patients.[7]

One of those substitutes is Matriderm® (MD) matrix (Medskin Dr. Suwelack Skin & Health Care AG, Billerbeck, Germany), which is of bovine origin and provides an elastic and stable neo-dermis formed by a three-dimensional matrix consisting of collagen type I, III, and V, additionally supplemented by elastin hydrolysate.[7,8]

Another aspect of traumatic full-thickness defects is their tendency to develop some sort of chronicity (eg, instable and invalidating scarring) strongly affecting a patients quality of life and leading to long-lasting and expensive treatments often resulting in extensive resection of tissue further reducing functionality or even ending in amputation.[9] For such cases, William S. Baer, an orthopedic surgeon at Johns Hopkins Hospital in Baltimore, proposed maggot debridement therapy (MDT) as an adjunct alternative to repetitive surgical debridement of infected wounds in the 1930s.[10] This therapeutic option fell into oblivion for decades after Fleming discovered Penicillin to fight infections but has recently regained worldwide popularity with the increasing problem of antibiotic resistances.[11-13] In selected cases, the application of sterile maggots as natural removers of necrotic or infected tissue has proven to be highly efficient in recent literature.[9]

MDT is widely used and accepted as it shows beneficial effects in the healing of acute and chronic wound infections.[9-14] In 2004, MDT was approved by the US Food and Drug Administration (510[k] #33391) as a medical device[12] and in Europe, MDT can be prescribed as a remedy by a physician even for outpatients.[15] One of the most leading hypotheses in the literature is that maggots possess antibacterial activity,[16,17] while others suggest inhibitory effects on biofilm formation[18] or a positive impact on the activation of the complement system.[15]

We present a case of a young woman with a devastating crush injury to her left leg in combination with non-dislocated fibula fractures, which could successfully be treated with VAC-Instillation® Therapy (Kinetic Concepts Inc.), Matriderm® augmented split-skin grafting and maggot debridement therapy.

2 | CASE PRESENTATION

A 41-year-old lady on a bicycle was overlooked by a truck driver while making a turn. Subsequently, she fell and her left leg got under the truck and was overrun. She was found fully conscious by emergency services and transported to a regular care hospital at first. Later that same day after initial surgical exploration in the theater, the intubated patient was transferred to our Level 1 Trauma Centre due to the extent of her injuries. In our shock room, we saw an already sedated and mechanically ventilated patient with a severe injury to her left lower limb with a Mangled Limb Severity Score (MESS) of 7.[19] A full-body CT showed no other injuries but non-dislocated fractures of the left fibular head and the distal fibula as well as severe soft tissue injuries of the left leg. The patient was immediately taken to our OR for exploration and debridement. We found an extensive decollement reaching from the distal thigh down to the ankle with extended damage to the anterior compartment of the lower leg, where over 90% of the musculature was lost preclinically. The Achilles tendon was torn close to the calcaneus, soleus and gastrocnemius muscles were contused and without any contact to the calcaneus but seemed to be vital. The plantaris tendon as well as *N. saphenus* and *N. suralis* was completely torn. The remaining neurovascular structures were carefully explored and were found to be unharmed. We performed a rigorous but gentle debridement as well as intensive flushing with a Ringers/Prontosan (B. Braun, Melsungen, Germany) solution (Dilution 2:1) of the soft tissue defects. We covered the defects with white polyvinylalcohol (PVA) foam dressings and partially adapted some of the defects with skin staples. Finally, we installed a Negative Pressure Wound Therapy (NPWT) system with a continuous negative pressure of 60 mm Hg. The patient was started on intravenous Heparin to prevent thromboembolic complications and Co-Amoxicillin-clavulanic acid for antibiotic therapy empirically (Figure 1A and B).

Two days later, we performed a second look with another extended debridement and refixation of the Achilles tendon. The wound margins were loosely adapted as far as possible and the remaining defects were again covered with white

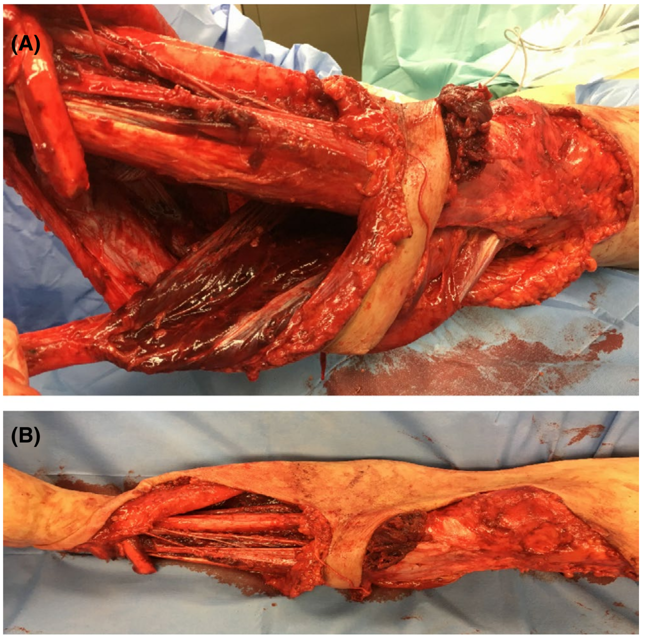

FIGURE 1 A, B: Status after initial debridement

PVA foam dressings. Furthermore, we started treating the wounds with a VAC-Instillation® System to further reduce the contamination and the bacterial load in order to achieve optimal conditions for wound closure, respectively, coverage. The PVA foams were instilled and flushed with a 4:1 Ringers / Prontosan solution (B. Braun, Melsungen, Germany) every 2–3 hours. Three more debridements and VAC-Instillation dressing changes were performed within the next 12 days.

Initial cultures obtained during these interventions showed growth of Bacillus cereus and Pseudomonas fluorescens; therefore, we changed the antibiotic regimen in consultation with the Department of Infectious Diseases to Tazobactam intravenously and Ciprofloxacin orally. Multiple following cultures taken in the theater during revision surgeries, showed no bacterial growth, and the wounds were always free of clinical signs of infection; therefore, we terminated the antibiotic therapy 4 weeks post-trauma.

Sixteen days post-trauma the wounds were clinically free of infection and perfusion of the remaining tissue was sufficient. In consensus with our colleagues of the Plastic Surgery Department, we decided not to rely on flap surgery as the defects were far too extensive. Therefore, we decided to perform the coverage of the remaining soft tissue defects with Matriderm® augmented split-skin grafting. The wound was flushed with 6 liters of a Ringers / Prontosan solution (2:1) and remaining necrotic tissue was debrided. At first, we covered the remaining defects with 1mm Matriderm® layer. The required split-skin grafts of 0.25 inches thickness were harvested from the patients left thigh in an almost circular manner in order the gain enough tissue to cover the defects. The grafts were then meshed 1:3. We applied the spilt skin grafts on the Matriderm and fixated them with staples and Fibrin glue. Finally, the skin grafts were covered with Mepitel® (Mölnlycke Health Care) and white PVA foam dressings, a NPWT with 70 mm Hg continuous suction was installed on top of the split-skin graft and a loose compression bandages were applied as padding (Figure 2A and B).

Five days post-mesh grafting there was the first bedside dressing change. Almost a 100% graft uptake was observed (Figure 3).

The following clinical course was uncomplicated in terms of wound healing. In regular dressing changes, the soft tissues were free of any signs of infection and the mesh graft was vital with excellent uptake. Due to the severe soft tissue damage and particularly to the extensive loss of musculature in the anterior compartment, the patient had symptoms of a pointed foot even though the neurovascular structures were intact. Due to the still healing mesh graft, we did not start therapy with an orthosis but rather treated the condition with gentle regular physiotherapy.

Forty-six days post-trauma we could discharge the patient with excellent healing of the mesh graft and transfer her to a rehabilitation facility. The wound care regimen comprised of regular application of 10% urea lotion, application of betadine solution on small defects within the mesh graft and coverage of the wounds with Mepitel® and a loose bandage. Careful weight-bearing was promoted in order to prevent the development of a permanent pointed foot. Flexion of the knee joint was only slowly and stepwise extended up to 90° to minimize sheer forces on the graft.

We continued clinical follow-ups in regular and short intervals at our outpatient clinic as well as at the rehabilitation facility. Forty-three days after the mesh graft procedure the patient started to develop mild macerations in an area above the Achilles tendon related to intense physiotherapy exercises with stress forces on the local soft tissue. Furthermore, a wound swap of that area proved positive in culture for Stenotrophomonas maltophilia, Enterococcus faecalis, and Staphylococcus lugdunensis. Therefore, we decided to resume the antibiotic treatment with Ciprofloxacin. About seven weeks after the mesh graft coverage, flexion of the knee up to 90° was possible and the patient left the rehabilitation facility. Further, the defects, except around the Achilles tendon, were only covered with a bandage during mobilization and left open overnight. About eight weeks post-surgery, we decided to debride the crust covering the area above of the Achilles tendon and started covering the defect with white PVA dressings soaked in Prontosan (Figure 4).

Eighteen weeks post-traumatic a peroneus orthosis and customized compression stockings were manufactured and adjusted to treat the pointed foot.

Unfortunately, the defect in the area of the Achilles tendon did not show sufficient healing about 12 weeks post-surgical coverage and we therefore began biodebridement therapy with maggots (sterile larvae of Lucilla sericata, in Biobag application 7 × 5 cm, Grossdietwill, Switzerland). Without any clinical signs of infection, the oral antibiotic regimen with Ciprofloxacin was stopped after 12 weeks. The biodebridement leads to a rapid improvement in the treated defect with growth of clean and viable granulation tissue.

After successful larval biodebridement of 4 weeks with changes of the Biobag with sterile Larvae twice a week, we decided to perform another mesh graft coverage of the defect above the Achilles tendon. The intervention was performed without any complications. After fixation with Vicryl stitches and Tisseel® fibrin glue (Baxter, Df2-1W Deerfield 60015–4625 United States USA), the mesh graft was covered with Mepitel® and a PVA foam applying a negative pressure wound system with continuous suction of 70 mm Hg (VAC, Kinetic Concepts Inc. 12930 W Interstate 10, San Antonio, TX, USA) (Figure 5A and B).

Transplantation 23 weeks after initial trauma.

Further, due to positive cultures for a mixed bacterial flora in the Achilles tendon wound, we started in close consultation with the Department for Infectious Diseases with an antibiotic therapy with Amoxicillin-clavulanic acid and Cotrimoxazole.

FIGURE 2 A, B: Intraoperative situation after Matriderm® augmented mesh graft at day 16 post-trauma

Five days post-surgery the NPWT-dressing was removed, and the mesh graft was vital with a nearly complete uptake.

We discharged the patient 8 days post-surgery. Weight-bearing was limited to 10kg, antibiotic therapy with oral Bactrim and Augmentin was continued.

With excellent healing and no signs of infection, the antibiotic therapy was stopped six weeks post-surgery. Weight-bearing was gradually increased to full weight-bearing over a time of six weeks. In order to reduce lymphedema patient fitted Jobst compression stockings were worn 4–6 hours per day. The soft tissue conditions improved continuously, and the swelling of the leg was significantly reduced by wearing the above-mentioned customized compression stockings. The gait of the patient with the peroneus orthosis continuously improved and got increasingly fluent.

FIGURE 3 First dressing change 5 days post-surgery

FIGURE 4 Months 3.5 post-trauma the defect above the Achilles tendon is not healing

About five months after the mesh graft coverage of the Achilles tendon area the soft tissue defect was completely, and mechanical stable covered.

The patient's already rather fluent gait could be improved further by a customized Heidelberger orthosis, which replaced the peroneus orthosis.

About 14 months post-trauma, the soft tissues of the left leg showed good healing with complete coverage of the former defects.

Three years post-traumatic, the patient is still regularly followed up in our outpatient clinic with excellent functionality with the Heidelberger orthosis and a fluent and free gait. The limitations of daily activities are only minimal, and the patient is back to work. She continues regular physiotherapy in order to further improve the long-term result after a devastating soft tissue injury.

Due to ongoing improvement of the (extensor) muscular strength of the lower leg, in the future, it is expected that patient will be able to walk fluently without an orthosis (Figure 6A-C).

3 | DISCUSSION

We reported a case of a young woman with a mangled limb that could be salvaged with a good long-term functional outcome. When initially treating a mangled limb, the surgeon in charge must decide—whenever possible in consensus with the patient or relatives—whether to choose the path of salvage or amputation. There is truly little unity within the community of trauma surgeons when it comes to this question with some studies supporting amputation over salvage.[20,21] Some even see successful salvage as inferior to early amputation based

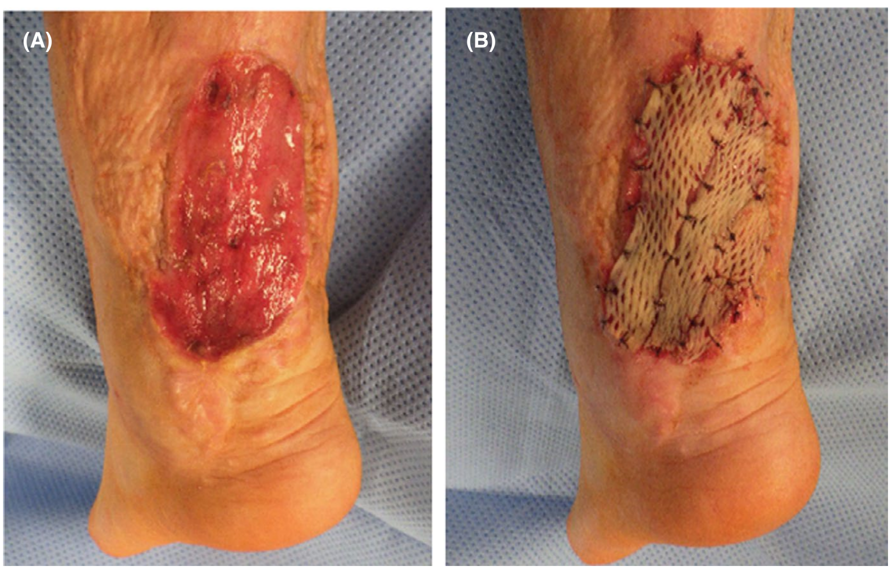

FIGURE 5 A, B Achilles tendon wound after biodebridement, followed by another mesh graft

FIGURE 6 A-C: Clinical outcome 3 years after the accident

on the longitude of the treatment and the psychological effects this can have for the patient.[22-24] The calculated MESS in our reported case was seven, suggesting primary amputation over salvage.[19] Nevertheless, in this case, we decided to choose the long path of limb salvage, which was always supported by the patient and her family. One main goal was to manage the defects without resorting to free flap surgery or arthrodesis, as this is related to major short and long-term morbidity.[21] We could restore a high level of functionality and even an adequate level of cosmetics with the comparatively simple measures of skin grafting, VAC-Instillation® technique, and biodebridement therapy. This approach relied on two cornerstones. First, the defects needed to be clean without clinical signs of infections and with sufficient vital granulation tissue and perfusion, which was achieved with rigorous debridement followed by VAC-Instillation® therapy. Different studies demonstrated that negative pressure wound therapy (NPTW) promotes a significantly faster wound healing process with improved perfusion and reduction of the bioburden.[25-28] Furthermore, adding continuous irrigation as it is the case with VAC-Instillation technique proved to further reduce the recurrence rate and improve the outcome in infected or contaminated wounds.[29,30] The second cornerstone of this approach was the augmentation of the split-skin mesh graft with Matriderm®(MD), which enabled us to dispense complex and morbidity afflicted flap surgery,[24,25] which could have not covered the whole extent of the defect anyway. MD functions as a dermal regeneration substitute highly improving the outcome of split-skin grafting when applied in combination[31] and with higher graft take rates compared to other comparable substitutes.[32] Different publications demonstrated a significantly increased elasticity of the newly formed skin after augmentation with MD compared to split-skin grafting alone, and thereby significantly improving functionality for the patient.[2,33,34] Another aspect is the one of cosmetic outcome. Min et al. found more similar tones of skin color compared to adjacent unaffected when mesh grafts were augmented with MD in comparison with skin grafting alone.[34] Furthermore, positive effects on sensory function in the augmented area were reported by Watfa et al.[35] Another technical advantage of Matriderm® compared to most other dermal substitutes is the possibility of a one-step approach[2,34] leading to a reduction of surgical procedures and shorter duration of hospitalization, thereby reducing the cost of hospitalization.

Despite our efforts, the patient developed a chronic wound in the area of the Achilles tendon, where the first attempt of Matriderm® augmented skin grafting failed. Retrospectively, we assume that starting a strenuous physiotherapy program too early leads to strong shear forces and that area finally leading to graft failure. As we already had positive experiences with biodebridement in chronic wounds prior to skin grafting, we discussed this treatment option with the patient. As the patient agreed and was happy to try avoiding as many surgical interventions as possible, we started maggot therapy (sterile larvae of Lucilia sericata) as an outpatient treatment with very satisfying results.

One of the authors (GNJ) has extensive experience with maggot biodebridement as he started this type of therapy for chronic wounds in the late 90s and since then applied it in hundreds of patients with mostly excellent results. The eggs from which the larvae hatch are disinfected by the provider prior to the hatching according to strict sterilization protocols, which guarantee sterile larvae that contained in a sterile biobag can be put directly on the wound.[9,36] In order to prove the sterility of the maggots before using them on patients one of the authors (GNJ) performed random swaps for microbiological cultures/examinations, which always came out negative indicating absolute sterility of the product. In the early days of biodebridement, the larvae used by William S. Bear were not yet sterilized, which unfortunately led to some cases of secondary infections, particularly by anaerobes, such as tetanus bacillus and the gas bacillus of Welch even though it is unclear whether those infections were actually caused by the maggots.[10] Nowadays though with the proper means of sterilization there are basically no reported cases of secondary infections due to the larvae, furthermore, the larvae seem to drastically reduce the bioburden within the treated wounds.[37-39]

The positive effect of the maggots on wounds is thought to be multifactorial and has been demonstrated in several publications.[9,10,40] The larvae of L. sericata have antibiotic effects and act as necrophages cleaning the wounds of dead and infected tissue.[41,42] The main mechanism for their beneficial effects on wounds is their extracorporeal digestive system. The maggots produce a multitude of enzymes such as tryptase, peptidase, and lipase and release them into their environment, breaking down infected and necrotic tissue, while leaving healthy tissue unharmed. The resulting semiliquid debris is absorbed and digested by the maggots.[9,43,44] Additionally, maggots create an alkaline environment by their secretion of ammonia, allantoin, and calcium carbonate[44] creating a barrier against bacterial colonization and stimulating the growth of granulation tissue.[10] Furthermore, the movement of maggots on the wound acts as a mechanical stimulus for growth of granulation tissue additionally promoting the wound healing process.[45]

4 | CONCLUSION

We presented a case of a highly complex soft tissue injury to the leg in combination with undislocated fibula fractures, which was successfully salvaged and treated with Matriderm® augmented split-skin grafting and biodebridement with maggots. The medical world is constantly evolving and getting more complex and specialized almost by the day. But in some cases, resorting to well-known and less complex solutions might be in the patient's best interest. Maggot biodebridement, in particular, in our point of view is a valid option for the treatment of complex wounds in sophisticated and well-equipped medical systems as well as in less developed settings as it is a cost efficient and highly effective treatment. The main challenge is an often negative or sometimes even anxious attitude of health professionals and patients regarding this type of therapy. Therefore, we think this exceptionally reliable, yet simple treatment strategy should be promoted more broadly so more patients can benefit from it.

ACKNOWLEDGMENTS

Published with written consent of the patient.

CONFLICT OF INTEREST

GN Jukema has been a speaker for Medskin Dr. Suwelack.

AUTHOR CONTRIBUTIONS

Maximilian Lempert: Data collection and writing. Hans-Christoph Pape: Critical revision. Gerrolt Nico Jukema: Data collection, writing, and critical revision.

ETHICS AND PATIENT CONSENT

No approval of the ethics committee was required for this manuscript as we only report on the standard treatment for such a case of injury. The patient concerned gave her written consent prior to writing this manuscript.

DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available from the corresponding author upon reasonable request.

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How to cite this article: Lempert M, Pape H-C, Jukema GN. Salvage of a mangled limb with Matriderm® augmented split-skin grafting and maggot biodebridement. *Clin Case Rep*. 2021;9:e04676. https://doi.org/10.1002/ccr3.4676