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Case report

Exposed tibial bone after burns: Flap reconstruction versus dermal substitute

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ABSTRACT

A 44 years old male patient had suffered extensive 3rd degree burns on both legs, undergoing thorough surgical debridement, resulting in both tibias being exposed.

Approximately 5 months after the incident he was referred to the Department of Plastic and Reconstructive Surgery of the University Hospital Gent, Belgium, to undergo flap reconstruction.

Free flap surgery was performed twice on both lower legs but failed on all four occasions.

In between flap surgery, a dermal substitute (Integra®) was applied, attempting to cover the exposed tibias with a layer of soft tissue, but also without success.

In order to promote the development of granulation tissue over the exposed bone, small holes were drilled in both tibias with removal of the outer layer of the anterior cortex causing the bone to bleed and subsequently negative pressure wound therapy (NPWT) was applied.

The limited granulation tissue resulting from this procedure was then covered with a dermal substitute (Glyaderm®), consisting of acellular human dermis with an average thickness of 0.25 mm.

This dermal substitute was combined with a NPWT-dressing, and then served as an extracellular matrix (ECM), guiding the distribution of granulation tissue over the remaining areas of exposed tibial bone.

Four days after initial application of Glyaderm® combined with NPWT both tibias were almost completely covered with a thin coating of soft tissue.

In order to increase the thickness of this soft tissue cover two additional layers of Glyaderm® were applied at intervals of approximately 1 week. One week after the last Glyaderm® application both wounds were autografted.

The combination of an acellular dermal substitute (Glyaderm®) with negative pressure wound therapy and skin grafting proved to be an efficient technique to cover a wider area of exposed tibial bone in a patient who was not a candidate for free flap surgery. An overview is also provided of newer and simpler techniques for coverage of exposed bone that could question the universal plastic surgery paradigm that flap surgery is the only way to cover these defects.

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1. Introduction

In full thickness burns of the lower legs the tibial crest is prone to becoming exposed due to the fact that it is only covered by a relatively thin layer of soft tissue.

Restoration of an adequate soft tissue cover for such defects can present a complex surgical challenge, especially when dealing with wider defects.

Prolonged cortical bone exposure, even without underlying fracture, can result in severe complications such as dehydration and bone necrosis leading to infection, osteomyelitis, possibly sepsis and ultimately even resulting in amputation [1].

As a general rule, whenever bone is exposed after a burn injury to the lower leg, the primary objective, in order to preserve bone viability, must be an early reconstruction of the soft tissue layer, providing the patient with maximal chances for rehabilitation and the opportunity to resume normal life [1–3].

Despite the fact that in recent years there have been several reports on the successful coverage of exposed bone (and tendons) with dermal substitutes, the wide majority of plastic surgeons, and especially those with a wide experience in microsurgery (as in our center), are still convinced that 'flap surgery' is by far the best (if not the only) way to cover these defects.

We hereby present a case that questioned this plastic surgery paradigm. In addition an overview of newer and simpler techniques for coverage of exposed tibial bone is provided as described in present literature.

2. Case report

In April 2011 a 44 years old male patient of African origin sustained extensive 3rd degree burns on both legs due to an accident with a torch setting his pants on fire. In another hospital thorough debridement was performed which resulted in extensive lower leg defects with bony exposure of both tibias. Already at an early stage holes had been drilled into the right tibia hoping this would result in granulation tissue formation.

Several months later, in September 2011, the patient was referred to the Plastic Surgery Department of the University Hospital Gent, Belgium, to provide adequate coverage of the long standing defects (now chronic wounds) of the lower legs with exposed bone (Fig. 1).

In a first surgical procedure, on September 15th, 2011, a free thoracodorsal artery perforator (TAP) flap was used to cover the defect on the left lower leg but despite revision the flap failed and eventually had to be debrided.

Two weeks later, on September 28th, 2011, a contralateral free TAP flap was transferred to cover the defect of the right lower leg but this flap also failed after a few days.

By means of intermediate therapy, NPWT (Exsudex®) was applied at −80 mm Hg. The dressing consisted of polyurethane (PU) foam (Ligasano®) combined with a Hydrofiber® silver dressing (Aquacel® Ag) for antibacterial purposes. NPWT was continued with a twice weekly dressing change schedule until November 23rd. At that moment the wound edges were granulating. On November 23rd, 2011 a dermal substitute (Integra®) was applied on both lower legs of the patient. Prior to Integra® application new holes were drilled in the exposed bone, this time in both tibias. The Integra® was combined with NPWT (Exsudex®). One week after application Integra® was removed due to bacterial overgrowth mainly caused by multiresistent *Pseudomonas aeruginosa* (+++).

To further reduce the bacterial load, intravenous antibiotics were started (Meropenem 1 g, 6x/dy) and the wounds were dressed daily with povidon iodine gel (Iso-betadine® gel) combined with paraffin gauze (Jelonet®) and a dry sterile gauze dressing.

On December 16th 2011, after 17 days of systemic antibiotic treatment which was continued over a total period of 6 weeks, two free gracilis muscle flaps were transferred to both lower leg defects. Both flaps failed again and eventually had to be debrided 10 days later.

After removal of the flaps, additional small holes were drilled in the bone cortex of the exposed tibias and with a chisel the upper layer of the non-vital anterior cortex was removed resulting in bleeding of the cortical bone.

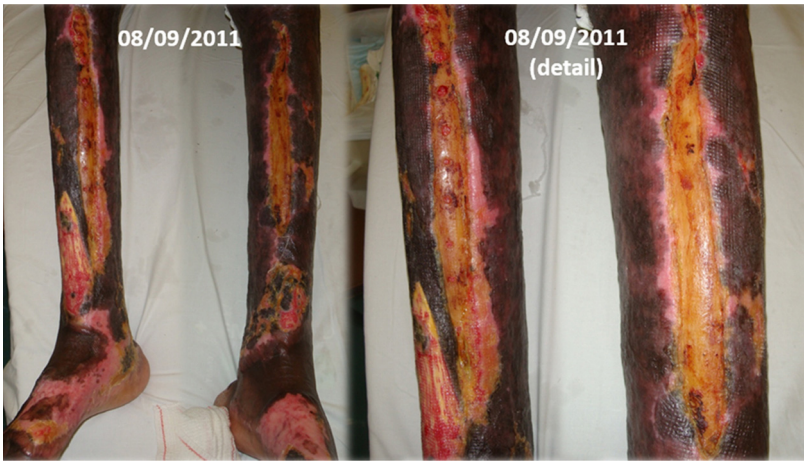

Fig. 1 – Wounds with exposed tibias (08/09/2011).

Fig. 2 – Situation after failure of Gracilis flaps (06/01/2012).

Intermediate therapy with NPWT (Exsudex®) was restarted (Fig. 2), again at −80 mm Hg with a twice weekly dressing change schedule and the dressing consisting of PU foam (Ligasano®) combined with a Hydrofiber® silver dressing (Aquacel® Ag) for antibacterial purposes.

This resulted in increased granulation tissue development but still leaving areas of exposed tibia on both legs of our patient (Fig. 3).

Based on the theoretical idea that a dermal substitute, such as Glycerol preserved acellular dermis (Glyaderm® – Euro Skin Bank, Beverwijk, The Netherlands), might serve as an extracellular matrix, guiding the distribution of newly NPWT-generated granulation tissue, to cover the remaining areas of exposed bone, it was decided to apply this dermal matrix in the operating theater on January 13th 2012.

Glyaderm® is a non-profit dermal substitute derived from glycerol preserved, human allogeneic skin (GPA). Sodium hydroxide (NaOH) is used to decellularize the GPA, resulting in a scaffold of human collagen and elastin. At present Glyaderm® is mainly indicated for bi-layered skin reconstruction of full thickness wounds [4,5].

Before Glyaderm® application (Fig. 3) both lower leg defects were extensively disinfected with povidon iodine dermic solution (Iso-betadine® Dermicum), followed by superficial curettage to refresh the wounds and make them bleed slightly. The Glyaderm® we would use was rinsed with sterile water in order to remove the glycerol solution in which it is preserved. Following rinsing the Glyaderm® was kept moist in sterile water until meshing.

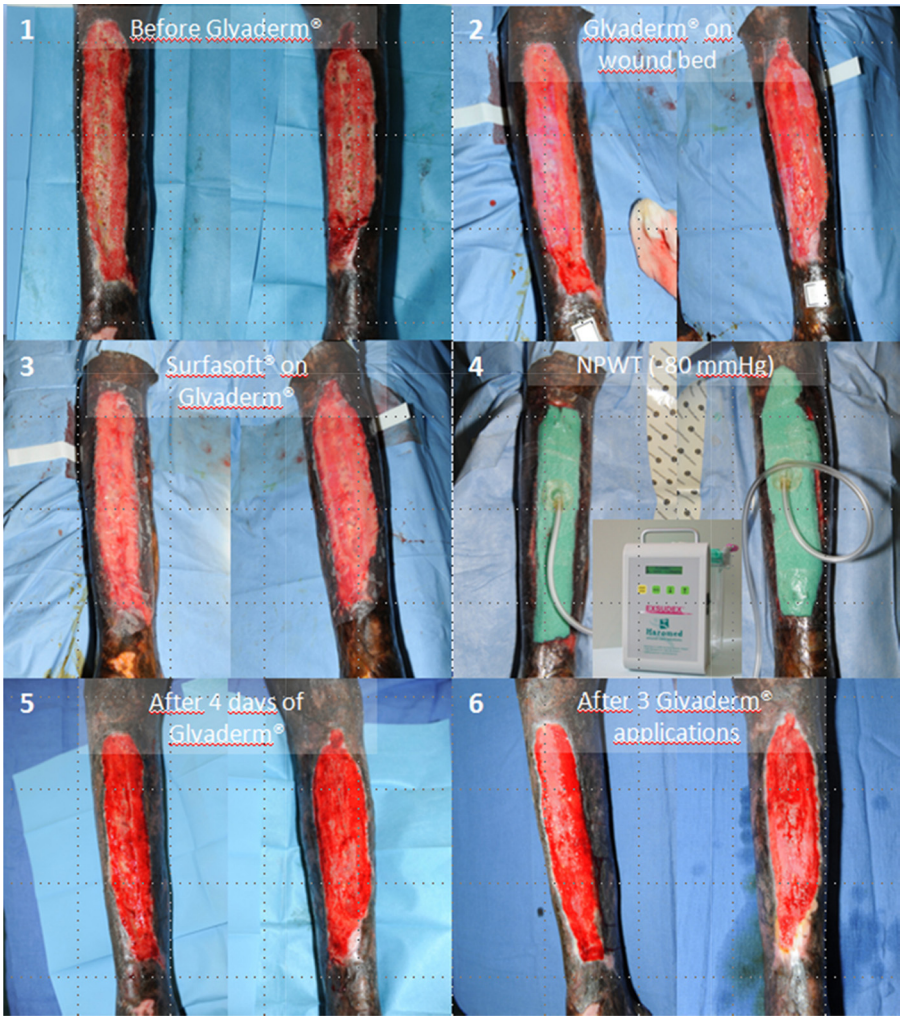

Fig. 3 – 1st Glyaderm application (13/01/2012).

Fig. 4 – Follow up autograft (24/02/2012).

After being meshed 1:1, the Glyaderm® dermal substitute was then sutured to the wound, covering both the areas with granulation tissue and the remaining exposed bone. Almost immediately after being positioned on the wound bed the extracellular matrix sheets with an average thickness of 0.25 mm completely blended in with the wound surface.

Over the Glyaderm® sheet a layer of transparent polyamide dressing (Surfasoft®) was applied, functioning in this case as a protective layer preventing ingrowth of granulation tissue into the PU foam (Ligasano®) we would use for NPWT (Exsudex®), and thereby minimizing the risk that Glyaderm® might be partially removed at first NPWT dressing change. Vacuum was set at −80 mm Hg.

First NPWT dressing change was performed on January 17th, 2012, 4 days after initial Glyaderm® application. The NPWT dressing was removed without problems, together with the Surfasoft®. What we observed were two clean lower leg wounds, almost completely covered with a layer of healthy granulation tissue. Only very small spots of exposed bone remained. This time a new NPWT dressing was applied directly on the new soft tissue layer. Vacuum settings remained at −80 mm Hg.

On January 25th 2012 and February 2nd a second and third layer of Glyaderm® were applied to increase the thickness of the granulation tissue layer developing over both tibias always using the same technique, except for the third application where premeshed Glyaderm® was applied bedside without suturing, but using the NPWT as a means of fixation.

By February 6th, 2012 the defects were completely covered with a thick layer of nicely granulating soft tissue and autografting was performed on February 10th, 2012. There was a 100% take of the skin graft (Fig. 4). Scar therapy was initiated and on February 20th, 2012 the patient was able to leave the hospital walking.

3. Discussion

This case report deals with the clinical problem of bone exposure in both tibias without fracture in a patient after debridement of full thickness burns on both lower and upper legs. The patient had sustained the burns approximately 5 months before his referral to the Plastic Surgery Department of the University Hospital Gent, Belgium, where he was send to specifically for free flap coverage of the exposed bone in view of the extensive microsurgical experience of this department.

The patient underwent four free flap reconstructions which all failed despite the fact that they were performed by a senior and very experienced microsurgeon. In between the second and third free flap procedure Integra® was applied but had to be removed already 1 week after application. As far as the first two free flap reconstructions and the Integra® are concerned, there was undoubtebly a factor of underlying, and at that point in time untreated, osteomyelitis combined with bacterial overgrowth mainly caused by multiresistent *P. aeruginosa* (+++).

But this doesn't explain the failure of the third and fourth free flap reconstruction.

Many plastic surgeons still consider muscle flaps as a better therapeutic option in case of infectious problems because of a better adaptation to the woundbed and because of a supposed increased tissue perfusion to wounds which are reconstructed with these flaps [1,6].

It is only at a later stage that the probability of heparin-induced thrombocytopenia syndrome [7–13] was revealed, as a possible major contributor to the four consecutive flap failures we observed.

Ultimately the two large areas of exposed tibial bone were successfully covered by means of a dermal substitute (Glyaderm®), negative pressure wound therapy and skin grafting thus demonstrating the efficiency of this technique as an alternative for flap surgery.

The surprisingly good results obtained in this specific patient raise the question to what degree this treatment protocol should be applied in comparable future cases?

The so-called 'reconstructive ladder' usually provides some first guidance in choosing the appropriate reconstructive technique to close a defect, which, as a general rule, should preferably be the simplest procedure that effectively solves the problem.

However the concept of the reconstructive ladder was originally proposed in 1982, so to date almost three decades ago, and since then several refinements and alternatives to the original concept have been suggested [14–18].

In the case presented here we were confronted with a discrepancy in reconstructive options between the techniques incorporated within the traditional reconstructive ladder (secondary intention healing, direct wound closure, skin grafting, tissue expansion, local flap, regional flap, free tissue transfer) and newer reconstructive tools more recently described to deal with exposed bone.

Overall three reconstructive options are presently at hand to cover exposed tibial bone:

- Flap surgery
- Negative pressure wound therapy
- Dermal substitutes (possibly combined with negative pressure wound therapy).

Important issues to be taken into account when considering either of these reconstructive procedures are the general condition of the patient, the size and the aspect of the defect, and the presence of functional considerations.

The main functional consideration in our case report was to avoid amputation and to give the patient the opportunity to resume normal life. The size of the area with exposed tibial bone, to be covered with soft tissue, after first debridement in Gent, measured approximately 50 cm^2 for the right leg and 40 cm^2 for the left leg. Apart from the fact that both wounds had evolved into chronic wounds showing bacterial overgrowth mainly caused by multiresistent *P. aeruginosa* (+++) and underlying osteomyelitis, there were initially no other known issues in relation to the general condition of the patient.

A mandatory first step in any similar case, regardless of the reconstructive technique chosen to cover the exposed tibial bone, is wound bed preparation, consisting of adequate debridement and reduction of the bacterial load [1–3,19–22].

In case of simple bone exposure, initial debridement will be mainly focused on the soft tissues whereas the exposed bone will principally require copious irrigation and freshening up [1].

Flap surgery, if successful, would have provided a solid and instant soft tissue coverage for the exposed tibial bone as described in our case report. Performing this procedure after radical debridement in an early stage would have minimized the need for additional wound bed preparation.

Several months later, after referral to our hospital, the only flap surgery possible in this patient with extensive burns to both lower legs was a free vascularized flap. Free tissue transfer, a specialized microsurgical technique, has revolutionized the treatment of lower extremity injuries, especially when associated with bone exposure, and therefore has become a first choice treatment and sometimes a last resort for limb salvage [1–3,23–25].

Normal success rate of free flap surgery in lower leg defects is 80–100% but decreases to 73% when trauma is repaired in a later stage after initial trauma [24].

As an alternative to free flap surgery, granulation tissue formation over the surface of the exposed bone can be stimulated by means of negative pressure wound therapy (NPWT) [3,21,26].

Several publications report on the benefits of NPWT as an advanced means of wound bed preparation in wounds with exposed bone [3,21,26–37].

Although most of this literature deals with NPWT in wounds with open fractures, there is no reason why these findings cannot be extrapolated to exposed bone after debridement of burns, the latter situation being less complicated.

In the treatment of open fractures, an international group of experts, after a review of the literature, recommends that NPWT may be used to downscale the complexity of wound closure and should be considered when primary closure is not possible after or in between debridements as a bridge to definitive closure, implicating also that NPWT should be stopped when delayed surgical (flap) closure is possible [34].

Delayed surgical closure technique will always depend upon the degree of functionality and the need for specialized tissue required in the body region to be repaired [34].

Since in our patient a free flap reconstruction was no longer an option, the residual defects with exposed tibias could clearly benefit from wound bed preparation with NPWT, followed by split thickness skin grafting once the bony areas are covered with granulation tissue.

The granulation tissue generated through NPWT will have to cover the exposed bone starting from the wound edges. Drilling or burring of the exposed bone is a well known technique to expose vascularized tissue whithin the bone which can result in extra granulation tissue formation.

Nevertheless, the time needed to achieve complete bone coverage with a sufficiently thick layer of granulation tissue only by means of NPWT remains a drawback. This is also demonstrated in our case report.

The application of a dermal substitute in combination with NPWT is a possible solution to overcome this problem. NPWT, if successful, results in granulation tissue formation, whereas the application of a dermal substitute over granulation tissue is able to guide the distribution of granulation tissue over the area where the dermal substitute was applied. NPWT has also been observed to promote the ingrowth of dermal substitutes [38–40].

In general practice, dermal substitutes nowadays are most commonly associated with tissue engineering. Probably the best known indication of dermal substitutes is that of temporary or permanent wound cover in deep partial thickness and full thickness burns aiming to provide complete restoration of the dermis before or in combination with split thickness skin grafting, but the spectrum of dermal substitute application is much broader than that, and also includes providing a permanent soft tissue coverage over exposed bone, in some cases in combination with NPWT [19,20,22,29,41–50].

Glycerol preserved acellular dermis (Glyaderm®) consists of collagen and elastin fibers and is the first non-profit dermal substitute derived from glycerol-preserved, human allogeneic skin [4,5,48].

From an anatomical point of view a dermal substitute, such as Glyaderm® is an extracellular matrix, which can serve as a scaffold for granulation tissue ingrowth, guiding the distribution of granulation tissue over areas of exposed bone.

In the case report described here, we report on the first patient in whom Glyaderm® was successfully used for the purpose of soft tissue coverage over exposed bone and we observed that the combination of Glyaderm® with NPWT resulted in accelerated overgrowth of two exposed tibias with adequate soft tissue formation.

The Glyaderm® application, as we performed it, had to be repeated in order to gradually increase the thickness of the granulating soft tissue layer developing over both tibias: the technique was very easy to perform, and no problems whatsoever were encountered.

4. Conclusion

In conclusion, when confronted with similar cases, we would advise:

- Adequate and thorough debridement also keeping in mind the need for reduction of the bacterial load, as a mandatory first step.
- Plastic surgeons should be involved from the beginning.
- Flap coverage of the exposed tibia should be attempted as soon as the patients condition allows for it.

- In case of flap failure, or if the patient is not a candidate for flap surgery, additional wound bed preparation, besides debridement, can be provided by means of NPWT, possibly preceded by drilling or burring of the exposed tibia.
- A dermal substitute, such as Glyaderm®, especially when combined with a NPWT-dressing, can serve as an extracellular matrix, guiding the formation of granulation tissue over the areas of exposed tibial bone thereby facilitating the coverage of the exposed bone by a thin layer of soft tissue. This technique can also be used in larger areas of exposed tibia.

From a functional and aesthetical point of view, bearing in mind the complexity of the procedure, the management of exposed tibia by means of a dermal substitute (Glyaderm®), negative pressure wound therapy and skin grafts proved to be an efficient technique and a possible alternative for flap surgery in the case report we described.

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