Delayed primary closure of fasciotomy wounds with Wisebands®, a skin- and soft tissue-stretch device

Yoav Barnea*, Eyal Gur, Aharon Amir, David Leshem, Arik Zaretski, Ehud Miller, Raphael Shafir, Jerry Weiss

Department of Plastic and Reconstructive Surgery, Tel-Aviv Sourasky Medical Center, affiliated with the Sackler Faculty of Medicine, Tel-Aviv University, Tel-Aviv, Israel

Accepted 27 February 2006

Summary

Background: Fasciotomy incisions for limb compartment syndrome usually cannot be closed primarily. The conventional method of wound closure with split-thickness skin grafting is effective, but it results in an insensate and disfiguring wound and is associated with donor site morbidity. We present our experience in delayed primary closure of fasciotomy wounds with Wisebands® (WB), a skin- and soft tissue-stretching device.

Patients: Between 2000 and 2003, we treated 16 patients with extremity fasciotomy wounds for which primary closure was not feasible.

Results: The Wisebands® devices achieved controlled stretching of the wound edges, including skin and underlying soft tissue, until primary closure was feasible. Fourteen patients (88%) had successful wound closure, two patients (12%) had minor wound complications that did not necessitate the removal of the device, and two patients had local wound complications (infection, intractable pain) and their devices were removed prematurely. Delayed primary closure was achieved at the initial surgery using intraoperative skin stretching in 3 of the 14 cases (21%). After a 2-year follow-up (1.3–4 years), the treated area showed stable scarring with good aesthetic outcome and no functional deficit.

Conclusions: The Wisebands® device facilitates closure of fasciotomy wounds with low complication rates and good functional and aesthetic outcome. Its application is simple and safe and requires a short learning curve. Nevertheless, appropriate patient selection, intraoperative judgment and close postoperative supervision are essential for optimal results.

© 2006 Elsevier Ltd. All rights reserved.

* Correspondence to: Department of Plastic and Reconstructive Surgery Tel-Aviv Sourasky Medical Center, 6 Weizmann Street, Tel Aviv 64239, Israel. Tel.: +972 3 6973320; fax: +972 3 6973890.
E-mail address: barneay@netvision.net.il (Y. Barnea).
Introduction

Compartment syndrome of an extremity may occur after severe trauma associated with fractures, vascular insult, burn, crush, or electrical injury.\(^1,11,23,27\) Treatment consists of expedient fasciotomy for alleviating compartmental pressure, thereby reducing the likelihood of permanent injury to muscles or nerves and preserving limb function.\(^1,11,23,27\) The fasciotomy wound may remain substantial and unsuitable for primary closure due to soft tissue swelling and retraction of the wound edges.\(^11,23,27\) Closure of these open wounds is traditionally achieved by split-thickness skin grafting, leaving a thin, fragile, insensate and often aesthetically unappealing result. Moreover, skin graft donor site morbidity may further aggravate the unaesthetic result and be accompanied by prolonged hospital stay.\(^11,23\)

An alternative option for fasciotomy wound treatment is delayed primary closure of the wound for which various mechanical devices and surgical techniques have recently been proposed.\(^1,3–8,12–20,22,24\) The keystone of delayed primary closure relies on the visco-elastic properties of the skin and the stretching potential of the soft tissues. This enables stretching of the wound edges by the application of mechanical forces.\(^9,10,18,21,26\) The skin lends itself to being stretched by virtue of its creep and stress-relaxation properties. Human skin under tension can be permanently stretched, providing that the force applied is meticulously monitored to ensure that it does not cause blanching or breakage of the collagen fibers in the dermis.\(^9,10,18,21,26\)

The Wisebands\(^1\) (WB) wound closure device is a skin- and soft tissue-stretching apparatus that permits delicate controlled stretching and approximation of the wound edges.\(^2\) The controlled load applied to the suture band causes gradual traction and tension to the wound edge so that a complete closure of the wound is achieved in a continual process of intermittent tension and relaxation.\(^2\) We now report our findings of delayed primary closure using the WB devices in 16 patients with fasciotomy wounds.

Patients and methods

Patients

Between January 2000 and January 2003, we treated 16 patients who underwent fasciotomy for limb compartment syndrome with delayed primary closure of the wounds using the WB devices. The fasciotomy incisions were performed by general, vascular or orthopaedic surgeons. This technique was reserved for wounds for which primary closure was not suitable and for patients who were compliant with the proposed treatment plan.

Information on age, sex, medical history, the anatomic location and etiology of the fasciotomy wound was collected for all the study patients. The original dimensions of the wound were measured and the number of devices used was recorded as were data on the time from the fasciotomy wound to the application of the devices and the total time of treatment with the devices.

Technique

After undergoing the fasciotomy procedures, the patients were encouraged to minimise mobility of the affected limb and elevate the extremity at all times in order to minimize dependent oedema. The wounds were covered with a wet-to-dry dressing that was changed every 8 h, and routine cultures were taken from the wound. Extremity elevation and dressing changes continued until the limb oedema had subsided, healthy granulation tissue had appeared in the wound and there were no signs of local infection. The patients were then taken to the operating room and given preoperative prophylactic IV antibiotic. Under local, regional or general anaesthesia the wounds were debrided of all devitalised skin and the soft tissue and wound edges were refreshed. The WB devices were applied to the wound and, in addition, a number of tension sutures were inserted but not tightened at this time but rather after the device had approximated the wound edges. The number of devices used for each wound varied according to the total dimensions of the wound, the extent of the underlying oedema, and the elasticity of the skin.

The device

The WB device consists of a tension feedback control mechanism, a flat plastic band (5 mm wide and 50 cm long) and a metal surgical needle, as seen in Fig. 1.\(^2\) The needle and its band are brought through the wound edges going down to the severed soft tissue under the skin defect.\(^2\) The surgical needle is removed and the band is inserted and held in place by a feedback tension control device. A controlled load is transferred to the wound edges by rotating a knob on the unit (Fig. 1). When the tension exceeds 1 kg/cm\(^2\), the feedback control mechanism relaxes and remains in the last "safe" position.\(^2\)

Tissue stretching is commenced intraoperatively by tightening the bands, pausing until the tension...
has been resolved, and then retightening the bands using the knob to apply appropriate tension. The stretching cycle is terminated if there is any compromising sign in skin viability (e.g., skin pallor, tautness of the skin, persistent local pain). When complete approximation of wound edges is achieved, the wound is either stapled or sutured. The devices are removed a few of days later, after verifying adequate wound closure. If the approximation had not been complete during the operation, the open wound is dressed with wet saline gauzes and daily stretching cycles are begun bedside in the department, until there is complete closure of the wound. Once the wound edges are sutured, patient follow-up takes place weekly for the first month following wound closure and then once monthly for 6 months. The final follow-up in this study took place at least 1 year and 3 months after the operation.

Results

Sixteen patients with limb fasciotomy wounds were treated using the WB devices. Thirteen patients were males and three patients were females, with a mean age of 40 years (range 21–74). Medical history disclosed diabetes in three patients, hypertension in two, and ischaemic heart disease in one. Four patients were active smokers during the fasciotomy wound incision.

The fasciotomy wounds were located in a lower extremity in 11 patients and an upper extremity in 5. The average fasciotomy wound length was 14 cm (range 7–26) and the average width was 5.8 cm (range 4–8). The aetiology for compartment syndrome included bone fractures in five patients, gun shot and shrapnel wounds in four, vascular surgery in three, crush injury in three and electrical injury in one.

The average time from fasciotomy to application of the WB devices was 7 days (range 5–16), and an average of two WB devices (range 1–3) were used per wound. Delayed primary closure of fasciotomy wounds was achieved in 14 patients. We could already achieve wound closure intraoperatively in three patients, owing to the possibility of applying rapid stretching cycles. The remaining 11 patients underwent daily postoperative stretching until there was full approximation of the wound edges. The average number of days from application of the devices to wound approximation was 6 days (range 0–15).

The WB devices had to be removed prematurely (before total wound approximation) in two patients. One of them suffered from intractable pain during the stretching process that did not respond to analgesics and required the removal of the bands and closure of the wound with a skin graft. This patient had a history of marijuana use and was not fully compliant with our medical instructions. The second patient had developed local wound infection with no signs of sepsis 3 days after applying the WB by which time the wound was partially approximated. The bands were removed and the wound was treated with wet-to-dry dressing until the local infection subsided. The wound was finally covered with a split-thickness skin graft.

Follow-up of the patients in our outpatient clinic averaged 2 years (range, 1.3–4 years). One patient was lost to follow-up after 2 months. The treated area showed stable scarring with good aesthetic outcome and no functional deficit. One patient developed a hypertrophic scar that subsided considerably with silicone sheath dressing. None of the patients required scar revision.

Case report

A 37-year-old man developed compartment syndrome in his left forearm after being involved in a road accident with a comminuted fracture of the distal humerus. The patient underwent immediate fasciotomy incision, resulting in a skin defect measuring 15 cm × 6 cm (Fig. 2(A)). The patient was treated with extremity elevation and wet-to-dry dressing changes, until the limb oedema had subsided and healthy granulation tissue had appeared in the wound (Fig. 2(B)). The patient was taken to the operating theatre where tension sutures were inserted loosely and two Wisebands devices were applied (Fig. 2(C)). The bands were gradually tightened until achieving complete approximation of the wound edges after 8 days. Long-term follow-up
revealed a soft, pliable and aesthetic scar, with no neurovascular compromise of the limb (Fig. 2(D)).

Discussion

Fasciotomy wounds can be treated by several techniques, including secondary healing, split-thickness skin grafting, and delayed primary closure. Skin grafting coverage of the wound results in a poor cosmesis, with prolonged inpatient hospital stay, and donor site morbidity. Our experience is that delayed primary closure of the wound results in normal skin coverage of the wound area, offering better protection and intact sensation of the area, with earlier limb function and better cosmetic outcome.

Because there is neither true skin nor soft tissue deficiency, fasciotomy wounds are more suitable for treatment by mechanically assisted delayed primary closure. Wiger et al.\textsuperscript{25} established that delayed primary closure of fasciotomy wounds is a safe treatment modality, with no neuromuscular compromise of the affected limb. There are numerous reported techniques for delayed primary closure of fasciotomy wounds\textsuperscript{1,3–8,12–20,22,24}, all harnessing the visco-elastic properties of the skin. We now describe our experience with the WB skin- and soft tissue-stretch device for delayed primary fasciotomy wound closure.

This method was developed as a consequence of enhanced understanding of the mechanical creep properties of the skin, which enable it and the underlying tissues to be considerably stretched beyond its intrinsic extensibility and within a relatively short period of time. Moreover, when tension is applied in cycles with relaxation periods between loads, one can achieve far greater elongation beyond intrinsic extensibility capabilities.\textsuperscript{9,14,18,21,26} The process of tissue stretching consists of tightening the device’s band, pausing until the tension has been resolved, and then retightening the band using a knob to apply the appropriate tension (Fig. 1). The stretching cycle is immediately terminated should there be any sign of compromising the skin’s viability (e.g., skin pallor, tautness of skin, persistent local pain).

Our series includes 16 patients with fasciotomy wounds that were treated with the WB devices. Successful delayed primary wound closure was achieved in 14 patients (88%). In two patients the devices were removed before total wound approximation and the wound was skin grafted. Interestingly, the final grafted wound area was approximately 50% of the original wound size, thanks to the already stretched skin.

The WB device was found to have a number of advantages over other skin stretching devices and...
methods. Surgical preparation for wound closure by means of this device required minimal wound dissection with no skin undermining, thus allowing maximal preservation of the neurovascular supply to the skin. The controlled feedback mechanism of the device allowed safe exertion of the stretching force until reaching the maximal load, whereby the device was switched to a neutral position to avoid skin- and soft tissue-compromise. Moreover, the stretching process was reversible and the load on the bands could be reduced should a local wound complication develop, and resumed after treatment until the completion of wound closure.

The WB device stretches both skin and soft tissue, minimising the "dead space" under the wound scar that could be the site of potentially infected haematoma or seroma. All the patients who achieved delayed primary closure of the wound had good functional and aesthetic outcome of the final scar with no sequelae in the affected limb.

Treatment with the device is not suitable for all patients and requires patient selection. Patients with low compliance or patients with very thin, atrophic, and fragile skin (e.g. systemic steroids treatment or after local radiation treatment) are poor candidates for treatment with the device. Wounds that are severely infected or have skin or soft tissue viability compromise are also not adequate to treat with the device.

Conclusion

We conclude that the Wisebands skin- and soft tissue-stretching device offers a simple and reliable mechanically assisted delayed primary closure of fasciotomy wounds, with a short technical learning curve. The application of the bands is reversible and can easily be removed at bedside in the event of wound complication. Judicious patient selection and intraoperative decision-making as well as meticulous postoperative care are essential for successful wound closure.

Conflict of interest statement

Dr. Jerry Weiss has stock ownership in the Wisebands Company Ltd.

Acknowledgment

Esther Eshkol is thanked for editorial assistance.

References