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REVIEW

Optimising Wound Closure Following a Fasciotomy

A narrative review

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توخي الإغلاق الأمثل للجرح بعد بَضْع اللفافة

مراجعة سرديه

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ABSTRACT: Compartment syndrome is a surgical emergency that could be resolved by a fasciotomy. However, performing substantial skin incisions may lead to life-threatening complications. This narrative review aimed to present the available methods of wound closure and preferential factors for using each technique. Viable and non-infected wounds were most often treated by gradual approximation techniques, such as the simple or modified shoelace technique, the prepositioned intracutaneous suture or several commercially-available mechanical devices. In addition, applying negative pressure therapy was found to be feasible, particularly when combined with approximation techniques. Skin grafting was reserved for severely-dehiscent wounds while other non-invasive approaches were considered for other subsets of patients with inadvisable surgical interventions. Treatment decision should be made in view of the patient's condition, ease of application, availability of resources, cost of treatment and aesthetic outcomes.

Keywords: Compartment Syndrome; Fasciotomy; Wound Closure Techniques; Negative-Pressure Wound Therapy.

الملخص: مُتَلازِمَةُ الحَيِّزِ هي حالة جراحية طارئة يمكن علاجها عن طريق بَضْع اللفافة. غير أن عمل شُقوق كبيرة في الجلد قد يفضي لمضاعفات تهدد الحياة بالخطر. والهدف من هذه المراجعة السردية هو عرض الطرق المتوفرة لإغلاق الجرح وعوامل تفضيل كل طريقة من تلك الطرق. وعادة ما تعالج الجروح العَيُوش وغير المصابة بالعدوى بطرق المقاربة التدريجية، مثل طريقة رباط الحذاء البسيطة أو المعدلة، أو طريقة الخياطة داخل الجلد المعمولة بشكل مسبق، أو باستخدام العديد من الأدوات الميكانيكية المتوفرة تجاريا. وبالإضافة لذلك، وُجد أنه يمكن تطبيق العلاج عن طريق الضغط السلبي، خاصة عندما يتلازم مع طرق المقاربة. أما التطعيم الجلدي فهو مقصور على حالات التفرز الوخيم للجروح. وقد يلجأ لوسائل غير باضعة عند المرضى الذين لا ينصح بالتدخل الجراحي في حالاتهم. ينبغي أن يؤخذ قرار نوعية العلاج بناءً على حالة المريض، وسهولة التطبيق، وتوفر الموارد، وتكلفة العلاج، والنتائج التَجْمِيْلِيّة.

الكلمات المفتاحية: متلازمة الحيز؛ بَضْع اللفافة؛ طرق إغلاق الجرح؛ علاج الجرح بالضغط السلبي.

Compartment syndrome (CS) is a surgical emergency condition that requires a timely diagnosis to preclude a potentially devastating outcome. It involves an increase in the intracompartmental pressure (ICP) due to an imbalance in homeostasis among the arterial flow, venous pressure and ICP.[1] CS is caused by vascular obstruction, fracture, injuries (e.g. crush or electrical injuries), excessive use of muscles and/or iatrogenic factors. The affected compartments may involve any muscle surrounded by *fascia* and are not limited to the axial skeleton; however, it mostly affects the compartments of the legs and, to a lesser extent, the compartments of the shoulders, arms, forearms, hands, thighs and buttocks.[2] Soft tissue necrosis and permanent disability may occur due to improper management. The gold standard for CS treatment includes a fasciotomy by performing an incision through the skin, fat and muscular *fascia* in order to reveal the underlying compartment and reduce the established pressure.

However, approximately 4–38% of the managed patients will develop unfavourable complications. In addition, failure of early identification of these complications has been associated with a two-fold increase in amputation rates and a four-fold increase in the risk of mortality.[3,4] Furthermore, 77% and 26% of patients can experience paraesthesia and tethered scars, respectively, which would lead to a significant reduction in quality of life.[5,6] Therefore, despite the importance of reducing pressure in the muscular compartments, surgical treatment of CS should only be performed after careful consideration of the post-operative aspects, such as pressure threshold and the degree of suspicion. However, early management of

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fasciotomy wounds is generally not recommended due to potential tissue oedema that may lead to necrosis, infection or recurrence of CS. This may eventually compromise the associated vascular pathology and/or fracture. Hence, fasciotomy performed for both therapeutic and prophylactic purposes should be managed as an open wound during the first 2–3 days followed by a primary closure of the wound.[7]

All wound closure techniques exploit the inherent viscoelastic and biomechanical properties of the skin.[8] A successful wound closure is defined as closure without the need for skin grafting, amputation or death,[4] for which there are numerous methods with various outcomes and can represent a challenge in terms of both timing and safety. This narrative review aimed to provide insights into the current techniques and their preferential application in selected groups of patients. The indications, complications, advantages and disadvantages of each procedure have been emphasised to ascertain the best approach to optimise wound closure.

Skin Grafting

In patient who underwent fasciotomies, skin grafting has been used for some time due to its safety, low cost and convenient dressing procedures compared to other delayed primary closure techniques.[9] Split-thickness skin grafting (STSG) is the treatment of choice for early coverage of fasciotomy wounds with persistent oedema and skin retraction. In a recent retrospective cohort study in the USA, STSG was the main surgical indication (40% of patients) for wounds for which primary closure was not possible due to swelling, whereas delayed primary closure techniques were utilised in only 18% of patients.[9] STSG was performed if the patient had either remarkable swelling of the lower extremity or open fractures and was more frequently performed on patients with proximal or tibial plateau fractures than patients with midshaft or distal fractures. This technique resulted in a significant reduction in the length of hospital stay (LOS) compared to other techniques.[10] In contrast, a larger retrospective study in the USA found that STSG procedures were associated with longer LOS compared to either vacuum dressing or dynamic tension-based techniques.[11]

In general, when applying tension via delayed primary closure is not possible, STSG may be the only available option for managing persistently dehiscent wounds, burns and wounds with a poor and friable edge.[7,12] Although the cost of STSG procedures increases due to long operative times and supplies required for grafting, this technique may be cost-effective due to shorter LOS and less frequent additional procedures compared to primary closure techniques. However, the STSG technique does have some limitations. Patients might experience pain at the donor site wound with noticeable scarring; this may increase the patient's morbidity and reduce mobilisation. Scarring can also occupy a wide area over the fasciotomy site and could affect the muscular function in the compartment. Furthermore, STSG procedures may be associated with cosmetic issues, adhesions between the muscles and tendons and reduced skin sensitivity [Table 1].[13]

Negative-Pressure Therapy

Since its introduction and development in the late 1990s, vacuum-assisted closure (VAC) has been used in order to close a wide variety of wound types and has contributed significantly to the improvement of healing and reduced requirements for reconstructive procedures.[14] VAC induces tissue microstrain that enhances wound healing by improving angiogenesis and cell division, discards the bacteria-rich exudate from wound edges and removes oedema from the extracellular matrix thereby improving the local blood flow and reducing proinflammatory cytokines.[14,15] As a result, healing of the marginalised tissue would be improved and progressive tissue necrosis may be reduced, which is of particular importance in reversing the CS-induced pathological changes. Furthermore, VAC dressings may have an advantageous role in bridging soft tissues following severe trauma associated with marked tissue loss.[16] With this technique, flap coverage may be omitted entirely in selected patients.[17]

For the management of fasciotomy wounds, VAC provides a powerful adjunct to surgical management or it can be utilised on its own. It decreases wound closure time, facilitates wound healing, reduces the time needed for a skin graft and increases the number of patients who can be good candidates for a feasible primary closure.[16] In open fasciotomy wounds, VAC dressings should be changed every 2–3 days either at bedside or in the operating room for large-sized wounds for better wound visualisation, irrigation and to ultimately maximise the chances of achieving staged primary closure or decreasing the size of skin grafts.

Yang *et al.* reviewed the records of 34 VAC-managed patients following leg fasciotomy procedures and found that the average time required for wound closure decreased significantly compared to matched controls (6.7 versus 16.1 days).[18] Weiland used hyperbaric oxygen in conjunction with VAC in order to enhance the reduction of oedema and found that wound closure ranged from 3–18 days in three patients.[19]

Table 1: Summary of studies investigating skin-grafting and dermal approximation techniques for primary wound closure after fasciotomy

Author and year of study	Location of study	Study design	Indication for fasciotomy	Type of treatment and sample size	Material used	Mean time to primary wound closure in days ± SD	Type of complication
VAC technique							
Bussell *et al.*[27] (2018)	Switzerland	Retrospective	Ischaemia, fractures and systemic diseases	• VAC (n = 19) • Temporary synthetic skin replacement (n = 9)	- • Epigard® (Biovision GmbH, Ilmenau, Germany)	9.37 ± 4.67 4.89 ± 2.32	• STSG (n = 1) and WI (n = 1) • None
Krticka *et al.*[23] (2018)	Czech Republic	Retrospective	Fracture	• VAC (n = 42) • Control (n = 21)	• SF = 125 mmHg • Combined dressing fabric	11 17	• STSG (n = 7), WI (n = 4), osteomyelitis (n = 2) and muscle necrosis (n = 3) • STSG (n = 10), WI (n = 7), osteomyelitis (n = 3) and muscle necrosis (n = 9)
Lee[20] (2016)	USA	Case series	Complicated wounds	• VAC (n = 2)	• VAC with instillation and dwell dime (SF = 125 mmHg)	-	• None
Saziye *et al.*[17] (2011)	Switzerland	Retrospective	IRI	• VAC (n = 7) • Conservative dressing (n = 8)	• SF = 75–125 mmHg • Gauze dressings	11 ± 8–13 15 ± 12-20	• STSG (n = 2) • WI (n = 3)
Weaver *et al.*[10] (2015)	USA	Retrospective	Fractures and soft tissue injuries	• VAC (n = 22) • STSG (n = 82)	- -	14.7 12.2	• No information available • No information available
Zannis *et al.*[16] (2009)	USA	Retrospective	Fractures and soft tissue injuries	• VAC (n = 68) • Wet-to-dry dressings (n = 74)	• SF = 125 mmHg • Normal saline-soaked dressings	7.1 9.6	• STSG (n = 29) • STSG (n = 35)
Shoelace technique							
Branco *et al.*[31] (2016)	Brazil	Case report	Open fracture	n = 1	• Elastic suture system	7	• None
Erdös *et al.*[37] (2011)	Austria	Case series	CS due to fractures and contusion of soft tissues	n = 24	• Elastic vessel loop with stables and VAC	11.9	• STSG (n = 3)
Lee *et al.*[21] (2014)	South Korea	Case series	Necrotising fasciitis	n = 8	• Elastic vessel loop with stables and VAC	16	• STSG (n = 2)
Matt *et al.*[11] (2011)	USA	Retrospective	Fractures and soft tissue injuries	n = 24	• Elastic vessel loop with stables and VAC	16	• STSG (n = 4) and WI (n = 2)
Murakami *et al.*[36] (2014)	Japan	Case report	Soft tissue injury	n = 1	• Elastic vessel loop with stables and VAC	7	• None
Saini *et al.*[30] (2018)	India	Prospective	Fractures and soft tissue injuries	n = 19	• Silk sutures	8.31	• WI (n = 1)
Sawant and Hallet[34] (2001)	UK	Technique description	-	-	• Elastic vessel loop with stables	-	• No information available
Zorrilla *et al.*[54] (2005)	Spain	Retrospective	Fractures and soft tissue injuries	n = 20	• Elastic vessel loop with stables	8.8	• None
Shoelace versus VAC technique							
Fowler *et al.*[25] (2012)	USA	Case series	Fractures and soft tissue injuries	• Shoelace (n = 49) • VAC (n = 7)	• Elastic vessel loop with stables • VAC device (Kinetic Concepts, Inc., San Antonio, Texas, USA)	19.2 23.7	• STSG (n = 9) and WI (n = 3) • STSG (n = 4) and WI (n = 2)
Johnson *et al.*[28] (2018)	USA	RCT	Traumatic injuries	• Shoelace (n = 5) • VAC (n = 9)	• Elastic vessel loop with stables -	7.6 12.9	• No information available • No information available

SD = standard deviation; VAC = vacuum-assisted closure; STSG = spilt-thickness skin grafting; WI = wound infection; SF = suction force; IRI = ischaemia-reperfusion injury; CS = compartment syndrome; RCT = randomised controlled trial.

Table 1 (contd.): Summary of studies investigating skin-grafting and dermal approximation techniques for primary wound closure after fasciotomy

Kakagia *et al.*[24] (2014)	Greece	RCT	Fractures and soft tissue injuries in the leg	• Shoelace (n = 25) • VAC (n = 25)	• Silastic vessel loop with stables • SF = 125 mmHg	15.1 ± 3.8 19.1 ± 6.1	• WI (n = 4) • STSG (n = 6) and WI (n = 6)
Suture technique							
Chiverton and Redden[40] (2000)	UK	Case series	Fracture of the lower limb	n = 6	• Prepositioned intracutaneous suture	-	• Broken suture (n = 1)
Dahners[55] (2003)	USA	Technique description			• Running near-near-far-far suture	-	• None
Janzing and Broos[39] (2001)	Belgium	Case series	-	n = 5	• Prepositioned intracutaneous suture	9 ± 3.5	• Second operation (n = 2). Traction under anaesthesia because of pain in one patient and another patient required additional sutures
Van der Velde and Hudson[56] (2005)	South Africa	Prospective	-	n = 11	• Bootlace nylon suture and VAC	7.5	• Skin necrosis (n = 1), broken suture (n = 1) and vacuum leak (n = 1)
Static tension strips technique							
Harrah *et al.*[42] (2000)	USA	Technique description	IRI	n = 6	• Plaster strips	-	• None
Weissman *et al.*[43] (2015)	Israel	Case series	-	n = 4	• Plaster strips	21	• Hypertrophic scar (n = 1)

SD = standard deviation; VAC = vacuum-assisted closure; STSG = spilt-thickness skin grafting; WI = wound infection; SF = suction force; IRI = ischaemia-reperfusion injury; CS = compartment syndrome; RCT = randomised controlled trial.

Another modification of the technique was presented by Lee, who used negative-pressure wound therapy with automated wound solutions instillation and dwell time.[20] Lee found that such a therapy promoted granulation tissue formation over the bone in a critically-ill and malnourished patient. Lee *et al.* recommended the use of an extended VAC therapy for large open fasciotomy wounds in eight patients with necrotising fasciitis, as it led to a significant reduction of wound area compared to the initial presentation without apparent complications.[21] Kakagia suggested that low suction pressure should be applied to a maximum of 100 mmHg, along with another wound approximation technique in order to avoid wound tissue rigidity owing to overgranulation and the resultant limitation of wound approximation.[22]

However, the effect of a single VAC application may be comparable only to the effect of dressings but not to other wound approximation techniques. Compared to traditional dressings, VAC therapy has led to a significant acceleration of wound healing and closure in addition to less time required for skin grafting.[23] Nonetheless, there may be a need for additional STSG in a considerable number of patients, ranging between 20–57%, which increases the overall treatment duration and cost.[16,17] In a prospective study, VAC therapy was associated with longer treatment durations and an increased demand for STSG with higher costs compared to the shoelace technique.[24] In a descriptive case series, Fowler *et al.* found that four out of seven patients who underwent VAC-assisted closure required skin grafting; this proportion was significantly higher than in patients managed by vessel loop closure (odds ratio: 5.9, 95% confidence interval: 1.11–31.24; $P = 0.04$).[25]

Delayed epithelialisation, another VAC-related issue, may become evident due to excessive granulation tissue formation that may grow into the dressings, exposing the wound to inflammation and infection.[24,26] In a recent retrospective study in children who underwent a lower extremity fasciotomy, VAC treatment was compared with a temporary synthetic skin replacement therapy and was associated with longer times to wound closure (9.4 versus 4.9 days) and more prolonged LOS (16.2 versus 9.9 days).[27] VAC-assisted wound closure was also prolonged compared to wounds closed by the shoelace technique, as demonstrated in multiple studies [Table 1].[24,25,28]

Dermal Apposition Techniques

Several techniques have been described for gradual approximation of wound edges. These techniques are frequently performed, such as daily bedside suture tightening, which leads to a gradual increase in skin length and reduction in the force required to maintain that length. Therefore, primary wound closure is possible and can be achieved after 7–15 days.[24] Gradual approximation can be achieved by multiple techniques such as using sutures, static tension devices and mechanical devices.

GRADUAL SUTURE APPROXIMATION TECHNIQUES

The shoelace technique was first described in 1986 and employs vessel loops, which are threaded in a criss-cross manner 48 hours after a fasciotomy;[29] subsequently, skin staples are used to secure the wound edges with regular loop-tightening every 48 hours [Table 1]. Intravenous analgaesia may be required during tightening sessions due to the associated pain. Ultimately, suturing of wound edges is performed, resulting in acceptable aesthetic outcomes and high wound closure rates.[25] Simple silk-suturing may be performed in a shoelace pattern following fracture-related fasciotomies which may be sufficient for wound closure without complications as shown in a series of 19 patients.[30]

While the shoelace technique is safe, inexpensive and minimally interferes with mobility, it lacks adequate strength to close large wound gaps. In areas of high tension such as point-loading sites, the staples may be dislodged.[24]

As a result, several variations of the shoelace technique have been proposed. Branco *et al*. used an elastic wire instead of vessel loops in a patient following tibial fracture-related CS; wound closure was successful within seven days.[31] Eid and Elsoufy used a shoelace apparatus consisting of one or two paediatric urinary catheters as well as skin staples without encountering major complications in a series of 17 patients with fracture-related CS.[32] Galois *et al*. used wide drainage tubes containing sutures to increase the contact area between the muscles and sutures and prevent muscular injury.[33] The drains were placed in contact with the muscles and were regularly tightened over the skin.[33] Sawant and Hallett secured the ends of vessel loops using a paper-clip instead of securing them with end-staples and knots.[34] This modification prevents pain and discomfort induced by tying and manipulation of the end-staples.

In addition, based on the results from eight emergency fasciotomies, Zenke *et al*. recommended the use of both VAC treatment and the shoelace technique to reduce the need of STSG and provide better aesthetic outcomes.[35] Such a combination was helpful in wound approximation in patients with severe soft-tissue injuries or abdominal injuries and could shorten the total treatment time compared to when each technique is used individually. Murakami *et al*. used the vessel loop technique in addition to VAC treatment in a patient with CS after an ischaemia-reperfusion injury; wound closure was achieved within one week without complications.[36] However, it should be noted that treatment costs would increase with the inclusion of VAC treatment and even more so if STSG is required.[11,37] This might be of considerable importance in a *milieu* of limited healthcare expenditures and austerity.

Riedl *et al*. first described an alternative approach for wound approximation, where a subcuticular suture was placed directly following fasciotomy without applying tension.[38] Within 3–5 days, progressive traction was applied and the patients were usually not required to undergo a secondary operation. Using this prepositioned intracutaneous suture technique, Janzing and Broos found that it provided excellent skin apposition within nine days of regular surgical wounds in five patients (100%) with acute limb CS; however, its efficiency may be questionable in traumatic wounds with irregular edges.[39] The subcuticular suture technique may be associated with inflammation around sutures and might lead to suture tears during closure attempts and subsequent suture replacement.[39,40]

STATIC TENSION STRIPS

Gradual closure of fasciotomy wounds can also be attained by applying non-invasive techniques relying on repeated application of plaster strips on the second day post-surgery. This method was initially reported by Mbubaegbu and Stallard who used two longitudinal strips on both sides of the wound with application of connecting (bridging) strips in an outpatient setting.[41] New longitudinal- and cross-strips should be added every 2–3 weeks until full wound closure is achieved. When using this method, surgeons should monitor the development of granulation tissue, which may inhibit wound closure. Similarly, Harrah *et al*. placed 1.2 cm-wide plaster strips in the same manner following application of a tincture of benzoin to decrease the risk of blistering and epidermal shearing.[42] However, this technique may not be feasible on large wounds where more tension on the strips is required as they may not withstand the tension of the protruding muscles. Moreover, the resulting scar due to tension may not be aesthetically acceptable, except for small fasciotomy wounds. Weissman *et al*. applied the same method in a paediatric population and showed that wound closure was achieved in 15–26 days without major complications; they suggested that this is an appropriate technique for patients for whom surgical interventions are inadvisable.[43]

DYNAMIC MECHANICAL DEVICES AND INNOVATIVE TOOLS

There are many innovative mechanical devices and techniques that focus on dermal approximation to achieve wound closure [Table 2]. Commercially-available devices exploit skin-stretching properties and mechanical creep; however, their typical role on the

Table 2: A summary of case series that employed dermal approximation techniques using dynamic mechanical devices/tools

Author and year of study	Device name	Number of patients	Treatment duration in days	Advantages	Disadvantages	Complication
Expensive device						
Barnea *et al*.[57] (2006)	Wisebands device	16	1–15	Providing a feedback control to safeguard when excessive skin tension is applied	Expensive and not readily available	Sepsis (n = 1), pain (n = 1) and scar (n = 1)
Janzing and Broos[39] (2001)	Marburger system	5	9	Materials needed for intracutaneous sutures are readily available	Expensive	Skin necrosis (n = 2) and skin grafting (n = 2)
Medina *et al*.[45] (2008)	Silver Bullet Wound Closure Device	8	5–10	Simple and efficacious	Daily tightening, numbness and tenderness of the scar	Pain (n = 2), scar (n = 3) and numbness (n = 2)
Ozyurtlu *et al*.[58] (2014)	V-Loc wound closure device using barbed sutures	5	8.6	Knotted sutures to prevent wound pulling back, faster tightening procedure and use of absorbable sutures	Rupture or lockups of the sutures	Necrosis (n = 1)
Taylor *et al*.[47] (2003)	Anchors	5	6–14	Equal distribution of tension forces	Expensive and not readily available	None
Inexpensive device						
Eid and Elsoufy[32] (2012)	Paediatric urinary catheters and staples	17	Average of 4.2 tightening sessions	Readily available and inexpensive	Point-loading	Skin necrosis (n = 5)
Govaert and van Helden[59] (2010)	Ty-raps	13	4–23	Stiff and very strong	Not readily available	Skin grafting (n = 1)
Kenny *et al*.[46] (2018)	Rubber bands	17	No information available	Readily available and used for large wounds	More than one application may be needed and qualitative assessment of the required tension	Skin grafting (n = 1)
Mittal *et al*.[49] (2018)	Dermotaxis	25	12	Easy to use and no point-loading	K-wire cut-out	Skin grafting (n = 2)
Pasha *et al*.[60] (2012)	Pasha device	9	5-8	Simple, cheap and user friendly	Not readily available	WI (n = 1)
Ravinder *et al*.[48] (2018)	Dermotaxis using Ravinder *et al*'s skin traction	100	8–15	Can be used in wounds with exposed bones	K-wire cut-out	Skin grafting (n = 12)
Rijal *et al*.[50] (2011)	Circular rubber bands plus longitudinal gauzes	3	8	Inexpensive and provides evenly distributed point-loading	Rubber band breakage and not suitable for active bleeders	None
Suliman and Aizaz[51] (2008)	Plastic bands	5	4–12	Simple, inexpensive and readily available	Risk of infection	Hypertrophic scar (n = 1) and WI (n = 1)
Walker *et al*.[61] (2012)	A silicon sheet fixed with a running Prolene suture	69	11.9	Safe, painless, provides constant wound control and easily removed	Risk of infection	STSG (n = 17)

WI = wound infection; STSG = spilt-thickness skin grafting.

biological creep seems to be less effective. For example, Sure-Closure (MedChem Products Inc, Woburn, Massachusetts, USA) employs frequent intraoperative tightening of the wound edges using two hooked, U-shaped arms; this process is interspersed with a 10 minute period of loosening the mechanical device.[44] The Silver Bullet Wound Closure Device (Boehringer Laboratories, Norristown, Pennsylvania, USA) is another mechanical device that relies on rotating an internal cylinder to tighten pre-inserted sutures that have passed from one wound side to the opposite edge.[45] However, the use of some of these mechanical devices has been restricted to distinct medical centres due to increased experience with these sophisticated procedures. Moreover, the use of such devices may be criticised due to the need for multiple applications of the technique, limited availability, lack of effective treatment for large wounds and the increased risk of skin necrosis and bulkiness.[46] Due to the potential costs of using these devices, they are generally limited to middle- or high-income countries such as USA, Canada and Belgium.[39,45,47] For example, the costs of wound closure using the Sure-Closure (MedChem Products Inc) and Silver Bullet Wound Closure

devices (Boehringer Laboratories) are $300–$500 and $575 USD, respectively.[45,47] Mechanical devices should only be used with sufficient clinical experience as the benefits of these devices may be questionable compared to other simple and approved techniques such as the shoelace or simple suture techniques.

On the other hand, several innovative approaches have been developed to provide simple and inexpensive solutions to close fasciotomy wounds. Ravinder *et al.*'s dermotaxis approach is a skin traction method involving two Kirschner wires which are connected by a specific compression device and are passed through the margins of the wound; subsequently, tightening is performed every 12 hours in a total of 5–7 tightening sessions.[48] The overall cost of such a method was estimated to be $5 USD per patient.[49] Recently, Kenny *et al.* developed a rubber band-based technique that costs <$1 USD for each application consisting of applying the rubber bands across the length of the wound or leaving the wound centre open according to the clinical condition with subsequent wound coverage with a dressing.[46] VAC therapy can also be utilised with such techniques in cases of large-gapping wounds. Rijal *et al.* developed another technique based on tying circular rubber bands to the marginal staples in a luggage-tag tying manner in addition to placing longitudinal layers of gauzes on the muscles to absorb fluid or discharge.[50] Suliman and Aizaz described a simple approach for wound closure using plastic bands which were originally used to bind electric cables (22 bands cost $1 USD).[51] Nonetheless, the use of these simple tools, including other dermato-traction techniques, may not be preferable in patients with atrophic, infected, doubtfully-viable or friable skin. However, STSG can be a better solution to maximise the cost-effectiveness of treatment.

Non-Invasive Wound Closure-Optimising Approach

LIMB ELEVATION

Bengezi and Vo recommended limb elevation to decrease the amount of time taken for oedema resolution and be able to perform a primary wound closure.[52] This approach depends on the rigorous enforcement of patients to keep the affected limb elevated on either an intravenous pole or at least five pillows with frequent checking for the laxity of the surrounding skin for optimal wound closure. This method is simple, has minimal costs and provides superior cosmetic outcomes. However, it may not be suitable for large or severely-affected wounds.

HEALING BY SECONDARY INTENTION

Healing by using skin contraction for gradual fasciotomy wound approximation is possible and would decrease overall cost of treatment.[53] However, wound closure only occurs after an average of 3–4 months and requires the patient to change their dressings 1–3 times during this period. In addition, complete normalisation of the scar conformation may take up to four years. Other limitations of this method include an increased risk of infection and muscular necrosis as well as significant delay implied in rehabilitation. Although healing by secondary intention has been abandoned in current surgical practice, it may be used in cases where delayed primary wound closure has failed or in associated wound-dehiscence circumstances.[22,53]

Conclusion

Both the amount of time taken to intervene and the fasciotomy technique that is used are crucial for optimal wound closure and may be more impactful than the type of wound closure technique itself. The current repertoire of methods of fasciotomy closure seems to be promising and additional methods are emerging. Generally, there is no preferred method for treatment, however, suture-based dermal approximation techniques are most widely used. In the instance of resource availability in developed countries, the outcomes of these techniques could be optimised by concurrent application of negative-pressure therapy. Surgeons should be aware of the advantages and limitations of each technique, in addition to the cost of treatment in low-income countries. Finally, non-invasive methods, such as the use of tension-inducing adhesive strips and limb elevation, may be considered for patients for whom surgical interventions are inadvisable.

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