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The Use of an Innovative Device for Wound Closure after Upper Extremity Fasciotomy

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Abstract
Introduction The purpose of this paper is to evaluate the Silver Bullet Wound Closure Device (SBWCD, Boehringer Laboratories, Norristown, PA), a new device for delayed primary closure of fasciotomy wounds.
Materials and Methods A retrospective review was performed over a period of 36 months of all patients with an upper extremity fasciotomy that could not be closed primarily. Cases that underwent fasciotomy closure with the SBWCD were separated from the patients that had a split thickness skin graft (STSG).
Results Seven patients had their wound closed with the SBWCD within 10 days (mean of 7.4 days). The seven patients that underwent STSG had their wound closed in an average of 8.4 days. The average number of days between the day of the fasciotomy incision and the date of the placement of the SBWCD was 1.9 days. STSGs were placed on the fasciotomy wounds on an average of 10.3 days after the date of the fasciotomy incision. We found that the SBWCD allowed for starting to approximate the edges of the fasciotomy wound at an earlier time when compare to STSG (2.1 vs 10.3 days).
Conclusions We feel that the SBWCD as a one-stage procedure provides a consistent and efficacious way to manage upper extremity fasciotomy wounds while minimizing the morbidity associated with STSG. Elimination of a second-stage procedure reduces hospital costs. Our findings may help to inform surgeons about an available alternative when an upper extremity fasciotomy wound is not amenable to primary closure.

Keywords Fasciotomy · Compartment syndrome · Trauma · Penetrating trauma · Blunt trauma · Fasciotomy closure

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Introduction

Compartment syndrome is a constellation of signs and symptoms, which develop in patients when a rise in pressure occurs in a closed (non-compliant) space [12, 16]. When compartment pressures exceed capillary perfusion pressures, tissue necrosis is likely to occur [13]. Compartment syndrome of the upper extremity has multiple etiologies, including fracture, intensive use of muscles, vascular ischemia, venous obstruction, crush or electrical injury, and also iatrogenic and idiopathic causes [7, 17]. Emergent fasciotomy is indicated to reduce the compartment pressure [10, 11, 15].

Primary closure of fasciotomy wounds is often difficult due to edema [1]. Some of the most common methods of closure include skin-stretching devices (Sure-Close®, Life Medical Sciences, Princeton, NJ, USA)[5, 9, 14], split thickness skin grafts (STSG) [13, 14], vessel loop techniques [2], dermatotraction techniques (External Tissue Extension®, Life Medical Sciences) [3, 4], static tension devices (Steri-Strips, 3M Surgical Products, St. Paul, MN, USA) [8], vacuum-assisted dressings (VAC®, Kinetic

Figure 1 The Silver Bullet Wound Closure Device (SBWCD) is a 9.5 cm stainless steel instrument that resembles a silver bullet.

Concepts, San Antonio, TX, USA), and secondary intention closure [6]. Lack of consensus regarding which of the previously described methods is most efficacious abounds in the literature [6].

Most fasciotomy wounds will need either delayed closure by advancement and/or STSG [5]. The STSG in upper extremity in addition to its unsatisfactory appearance has added disadvantages of pain at the donor site, creation of an additional wound, insensate skin over the fasciotomy site, and muscle to tendon adhesions [9].

We have developed a new device, which assists in the delayed primary closure of fasciotomy wounds. Our wound closure device is a 9.5-cm stainless steel instrument that resembles a silver bullet (Figs. 1 and 2). The Silver Bullet Wound Closure Device (SBWCD, Boehringer Laboratories, Norristown, PA, USA) provides traction across the wound

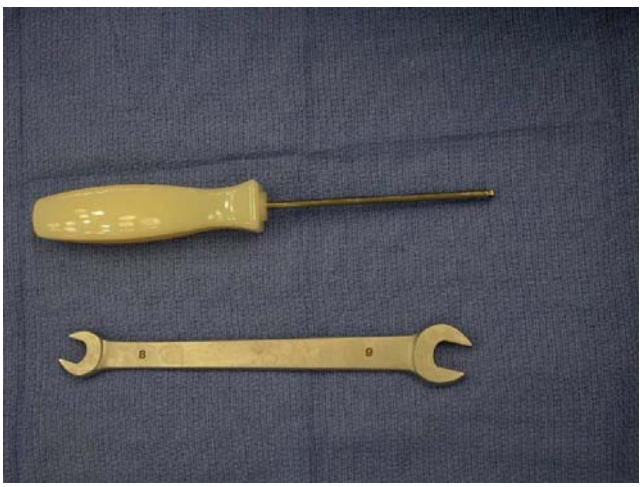

Figure 2 Torque driver (turns internal cylinder) and stabilizing wrench unit.

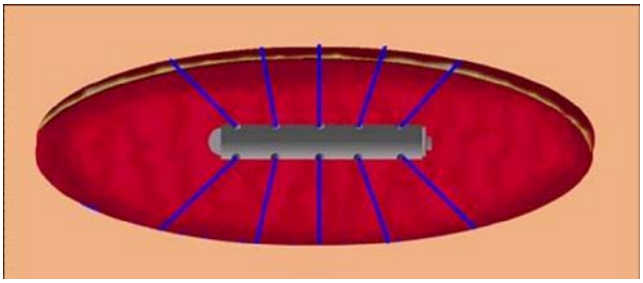

Figure 3 Diagram of the SBWCD held in the middle of an open wound. The SBWCDs are sutured into the wounds with 0 polypropylene sutures in an interrupted fashion.

and promotes faster healing (Figs. 3, 4, and 5). The purpose of the current study was to compare the fasciotomy closure efficacy between the SBWCD and STSG.

Materials and Methods

At Temple University Hospital in Philadelphia, a regional trauma center, fasciotomy wound closure is managed either with the SBWCD, STSG, secondary intention closure, or by primary closure. We performed a retrospective review over a period of 48 months (January 2003 to January 2007) of all patients with a fasciotomy wound that could not be closed primarily. Fourteen patients had upper extremity fasciotomy wounds unable to be closed primarily. All the fasciotomies were performed for compartment syndrome.

Ten patients in this series had associated penetrating trauma to the abdomen, thorax, and extremities. Four patients developed compartment syndrome due to extremity infections secondary to intravenous drug use or due to sustained blunt trauma to the extremity. Seven patients underwent major vascular repairs. On the postoperative course, the edema and friability of the tissues on the fasciotomy wounds were assessed to determine if primary closure was possible. Once primary closure was not possible, each patient chose the type of closure for the

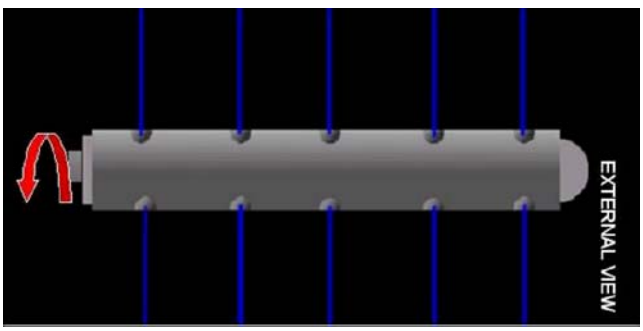

Figure 4 The rotation of the internal cylinder is used to contract wounds.

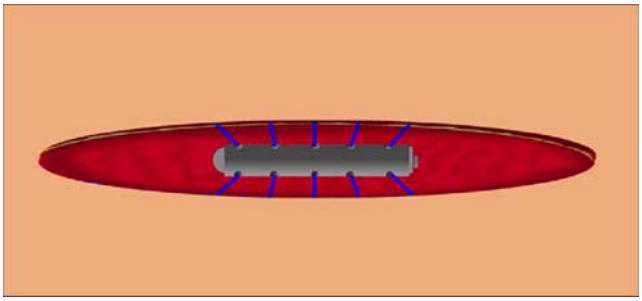

Figure 5 Diagram demonstrating wound edges approximation.

fasciotomy wound (SBWCD or STSG). Eight patients had their wounds managed with the SBWCD (Table 1). A total of six patients underwent STSG to their fasciotomy sites (Table 2). Of note, in our institution, we do not use any other type of delayed closure method besides the SBWCD.

The SBWCDs were placed in the operating room within 5 days from the day that the decompressive fasciotomies incisions were made (Figs. 6 and 7). The SBWCDs were sutured into the wounds with 0 polypropylene sutures in an interrupted fashion. Usually, an upper extremity fasciotomy wound required three devices per incision (Fig. 8). Sterile wet to dry dressings were applied over the SBWCD. Dressings were changed twice a day. Wounds were assessed on a daily basis for possible closure without tension by tightening the SBWCD (Figs. 9 and 10). Delayed primary closure was completed in the operating theater in eight patients with the SBWCD using minimal tension with number 0 polypropylene sutures (Fig. 11).

The STSGs were applied to wounds within 15 days after the fasciotomy (Table 2). Dressings were left in place from 3–5 days (an average of 4.2 days). The attending surgeon noted the percentage of graft take. The range for qualification of a "good take" was from 75 to 100% of the entire graft surface and was considered a closed wound.

All patients were treated with intravenous antibiotics for at least 24 h after each surgical intervention.

Table 1 Patients that underwent fasciotomy wound closure with the SBWCD.

Case No.	Age (Years/Old)	Gender	No. of Days (Before SBWCD)	Closure Time (Days)	Hospital Stay (Days)
1	27	M	0	9	21
2	41	M	4	8	16
3	31	M	5	10	19
4	43	M	1	6	20
5	33	F	0	7	15
6	38	M	0	5	30
7	26	M	3	8	25
8	25	M	2	6	21

SBWCD Silver Bullet Wound Closure Device; *Case No.* case number; *No. of days* number of days between the fasciotomy and the SBWCD placement; *Closure Time* time interval between the placement of the SBWCD and primary closure; *Hospital Stay* length of hospital stay; *F* female; *M* male

Table 2 Patients that underwent fasciotomy wound closure with STSG.

Case No.	Age (Years/Old)	Gender	No. of Days (Before STSG)	Closure Time (Days)	Hospital Stay (Days)
1	15	F	10	4	62
2	60	M	12	6	6
3	33	M	17	5	32
4	44	F	9	14	30
5	40	M	7	16	25
6	40	M	7	10	54

STSG Split thickness skin graft; *Case No.* case number; *No. of Days* number of days between the fasciotomy and split thickness graft placement; *Closure Time* time interval between the placement of the SBWCD and primary closure; *Hospital Stay* length of hospital stay; *F* female; *M* male

Results

Eight patients had their wound closed with the SBWCD within 10 days (Table 3, mean of 7.4 days). The average amount of time between the day of the fasciotomy incision and the placement of the SBWCD was 1.9 days (Table 3). It varied due to multiple factors such as the day that the consultation was placed to evaluate the wound and the general medical condition of the patient.

The six patients that underwent STSG had their wound closed within 16 days (Table 3, mean of 9.2 days). The

Figure 6 Day 0; fasciotomy wound (Table 1; patient number 6).

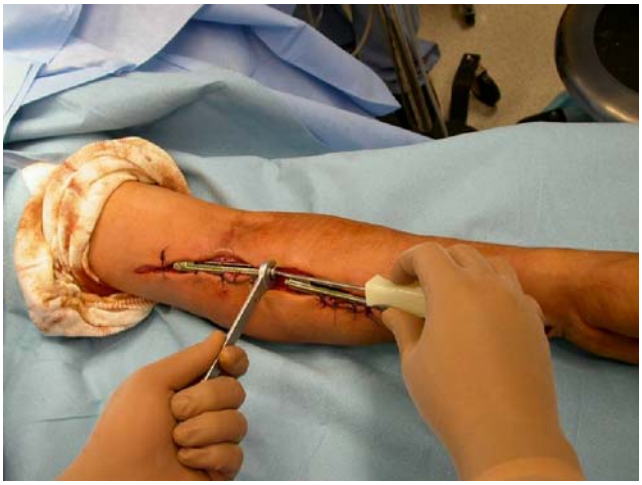

Figure 7 Day 0; placement of SBWCD.

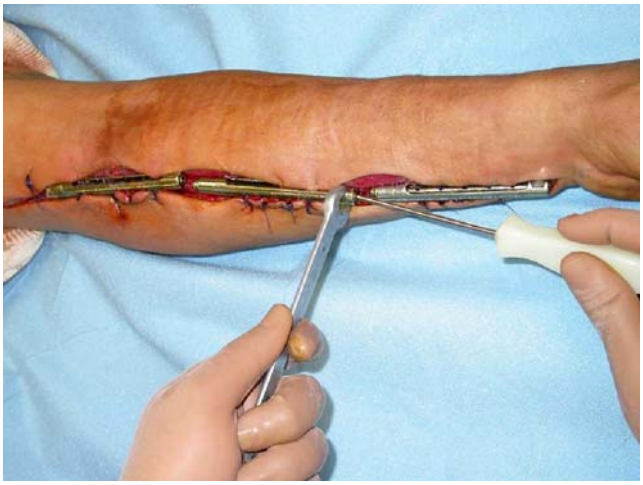

Figure 9 Day 2; bedside wound edge approximation.

average number of days between the day of the fasciotomy incision and the placement of the STSG was 10.3 days (Table 3). It varied according to the day the consultation was placed, the degree of edema on the extremity, and the general medical condition of the patient.

Most of the patients had co-morbidities related to the initial mechanism of injury that prolonged their hospital convalescence. For the majority of the patients in this study, the fasciotomy wound was not responsible for their length of hospital stay.

The average amount of days between the day of the fasciotomy and the day of the SBWCD placement was significantly shorter when compared to the interval of time for STSG placement. We were unable to appreciate a significant difference between the closure time for the SBWCD and STSG (Table 2; 7.4 vs 9.2 days).

Mean follow-up at clinic was 14 months (6 to 30 months). Two patients of the SBWCD group complained of persistent scar tenderness (Table 4). Non-steroidal anti-inflammatory drugs provided relief to the patient reporting mild pain. The patient with moderated pain required a referral to a pain clinic. In the STSG group, three patients complained of mild extremity pain (Table 5). All of these patients experienced pain relief with non-steroidal anti-inflammatory drugs. In the SBWCD group, only two patients complained of mild numbness over the extremity (Table 4). Five patients of the STSG group reported having numbness on the extremity (Table 5). After closure with the SBWCD, a total of three patients reported to have an extremity with an unsatisfactory cosmetic appearance (Table 4). Five patients from the STSG group complained of having an extremity with an unsatisfactory appearance

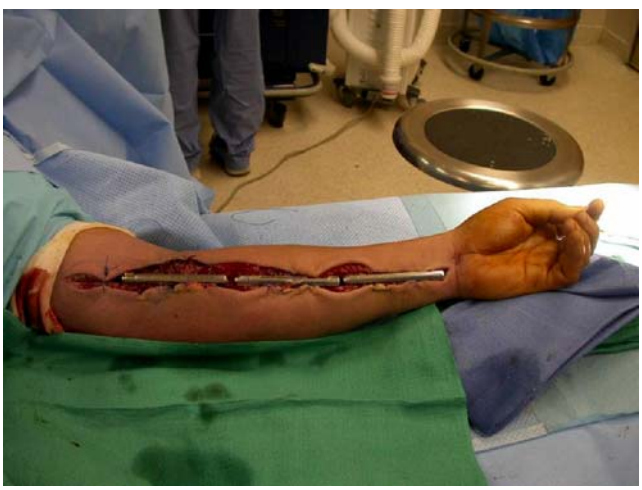

Figure 8 Day 0; wound with SBWCD.

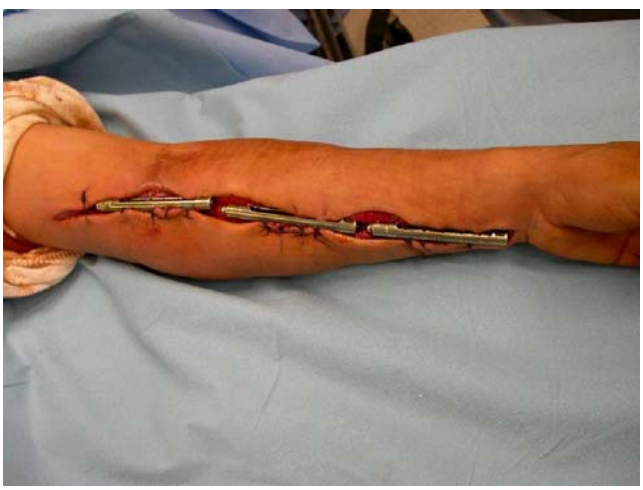

Figure 10 Day 2: wound after SBWCD tightening.

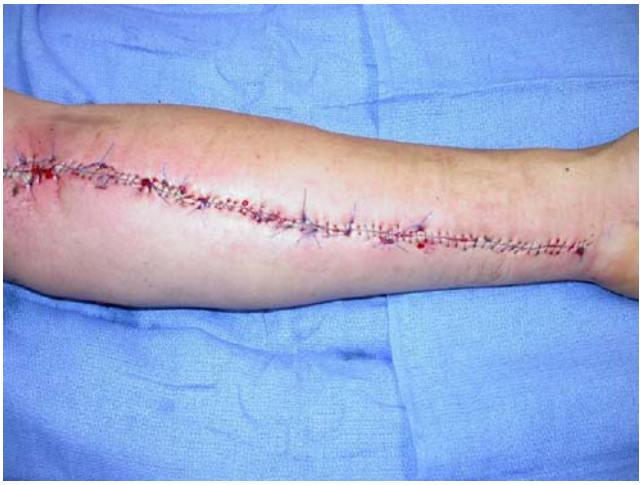

Figure 11 Day 5; wound closed primarily.

Table 4 Rating of postoperative outcomes with the silver bullet wound closure device®.

	Number of Patients
Severity of pain	
Asymptomatic	6 out of 8 patients
Mild	1 out of 8 patients
Moderate	1 out of 8 patients
Severe	none
Sensation	
Asymptomatic	6 out of 8 patients
Mild numbness	2 out of 8 patients
Moderate numbness	0 out of 8 patients
Severe numbness	0 out of 8 patients
Appearance	
Satisfactory	5 out of 8 patients
Not satisfactory	3 out of 8 patients

(Table 5). None of the patients that underwent fasciotomy closure with SBWCD required or requested reoperation on the extremity. A total of five patients of the STSG group requested reoperation on the extremity mainly due to its appearance and scar numbness.

In our experience, the patient charge for one SBWCD was $575. This represented an approximate cost of $1,150 for an upper extremity fasciotomy wound. The device is autoclavable and reusable.

Discussion

Our results suggest that the SBWCD may provide a more consistent and efficacious way to manage fasciotomy wounds because it starts approximating the edges at an earlier time. Furthermore, the SBWCD eliminates a second-stage procedure reducing hospital costs. In the other hand, patients that underwent STSG experienced disadvantages such as having a fasciotomy wound for a longer time (when compare to patients that had the SBWCD), pain at the donor site, creation of an additional wound, insensate skin over the fasciotomy site, muscle to tendon adhesions, and poor cosmetic results.

We found in this study and with ongoing use of the SBWCD that it was simple to use and efficacious for closure of fasciotomy wounds secondary to compartment syndrome (regardless of the etiology). Although our patients had their wounds re-approximated while they were in the hospital, the SBWCD has the potential to be placed at the bedside or in the office. Most importantly, the use of SBWCD enables us to avoid delayed removal of STSG as requested by most our patients at a follow-up day.

In our institution, when a fasciotomy wound is not amenable to primary closure, the SBWCD is the preferred alternative method in our institution and we recommend its use.

Table 3 Mean value for patients' age, days before closure (SBWCD or STSG), and hospital stay.

Type of Closure	Mean Age (Years/Old)	Mean No. of Days (Before SBWCD or STSG)	Mean Closure Time (Days)	Mean Hosp Stay (Days)
SBWCD	33.0	1.9	7.4	20.9
STSG	38.7	10.3	9.2	34.8

Mean No. of days Mean number of days between the day of the fasciotomy and the placement of the SBWCD or STSG; *Mean Closure Time* mean number of days between the day of the fasciotomy and closure of the wound with the SBWCD or STSG; *Mean Hosp Stay* mean number of days of hospital stay; *SBWCD* Silver Bullet Wound Closure Device; *STSG* split thickness skin graft

Table 5 Rating of postoperative outcomes for split thickness skin grafting.

	Number of Patients
Severity of pain	
Asymptomatic	3 out of 6 patients
Mild	3 out of 6 patients
Moderate	none
Severe	none
Sensation	
Asymptomatic	none
Mild numbness	1 out of 6 patients
Moderate numbness	3 out of 6 patients
Severe numbness	2 out of 6 patients
Appearance	
Satisfactory	1 out of 6 patients
Not satisfactory	5 out of 6 patients

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