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A Suitable Option for Gustilo and Anderson Grade III Injury

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Background: The management of Gustilo and Anderson grade III injury remains difficult, particularly due to the incidence of wound infections, delayed fracture union, and traumatic extremity amputation. However, little data is available on delayed skin graft or flap reconstructions of Gustilo grade III injury, especially using new technologies of wound coverage, such as vacuum sealing drainage (VSD) combined with limited internal and/or external fixation.

Material/Methods: Between June 2008 and May 2013, we performed the VSD technique combined with limited internal and/or external fixation on 38 patients (22 males and 16 females, with a mean age of 36.5 years) with Gustilo and Anderson grade III injury. VSD was regularly changed and delayed skin grafts or flaps were used to cover the defect. Two patients were lost to follow-up, and the remaining 36 were available for evaluation. The complications, wound healing, infections, and bony union were assessed for a mean duration of 2.5 years (range, 1–4 years).

Results: Complications were seen in 5 of the 36 cases: 2 cases had infection alone, 1 case had delayed union or nonunion, 1 case had infection and delayed union, and 1 case had wound necrosis, infection, and nonunion. VSD was regularly changed 2–6 times. Morphological appearance and functional recovery were satisfactory in all cases.

Conclusions: Using VSD before skin grafts or flaps coverage, combined with limited internal and/or external fixation, is a suitable option for Gustilo and Anderson grade III injury.

MeSH Keywords: General Surgery • Internal Medicine • Vacuum drainage (VSD)

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Background

The management of Gustilo and Anderson grade III injury remains a difficult surgical problem [1–8], including the incidence of wound infections, delayed fracture union, and traumatic extremity amputation. Impaired vascularity, devitalized tissue, and loss of skeletal stability lead to increased susceptibility to infection, nonunion, delayed bone healing, and limited limb function after injury. The essential aspects of managing such injuries include infection prevention, soft-tissue coverage, fracture fixation, functional improvement, cosmesis, adjacent joint mobility, and cost. It is difficult to accurately judge the range and severity of the defect and to achieve primary repair with microsurgical techniques after debridement in the Emergency Department. Different surgical methods have been developed to resolve these issues [2,3,5–7], which include skin grafts, local flaps, vascularized flap grafts, and free-flap transfers. Some surgeons recommend definitive soft-tissue coverage at the earliest possible time, preferably within the first 72 h after injuries [4], in order to prevent infection and improve bone healing. However, this is often impossible because of wound contamination, pre-existent infection, complicated fracture, associated injuries accompanied by hemodynamic instability, microcirculatory dysfunctions, or systemic incapabilities. A temporary closure is needed to prevent the exposed vital structures from desiccation, bacterial contaminants, and microcirculatory dysfunctions based on systemic inflammation or edema [4,7].

Vacuum sealing drainage (VSD) is a progressive treatment of complex wounds for deep drainage, as opposed to the other surgical drainage technologies [9]. VSD was first used in 1992 by Dr. Fleischmann of ULM University for the treatment of soft-tissue defects in orthopedics and wound infections. Currently, this approach is widely used in clinical practice for the protection of large wounds in the extremities to prevent infection, stimulate granulation, and reduce the area requiring flap cover, thereby improving the success of subsequent surgery, reducing postoperative complications, and promoting functional limb recovery, VSD also used for wound dehiscence after malignancy operations [3, 8–10]. James et al. compared vacuum-assisted closure (VAC) to conventional wrapping in a randomized study of patients with severe open fractures [2]. After thorough debridement in the Emergency Department, the wounds of the experimental group were covered using a VAC system (Kinetic Concepts, Inc., USA), whereas wounds of the control group were treated with conventional sterile gauze wrapping. Wounds in the experimental group demonstrated significantly better granulation formation. Moreover, the number of patients with osteomyelitis and local infection after wound repair was significantly lower in the experimental group.

The purpose of this study was to retrospectively assess the clinical outcome of VSD technique combined with limited internal and/or external fixation in the management of patients with Gustilo and Anderson grade III injury.

Material and Methods

The present study was conducted in accordance with the ethics standards of the Committee on Human Experimentation of the institution in which the research was conducted and in accordance with the Helsinki Declaration. Between June 2008 and May 2013, we treated 38 cases of Gustilo and Anderson grade III injury, which met the study inclusion criteria (Table 1)

Table 1. Inclusion and exclusion criteria used in the study.

Inclusion criteria
Grade-III A and B open injuries of limbs without vascular deficit
Wound contamination could not be primarily apposed without debridement
Injury to debridement interval <12 hours
Presence of bleeding wound margins that could not be apposed without tension
Stable fixation achieved by internal/external fixation
Exclusion criteria
Grade-I, -II and -III C injuries
Polytrauma involving chest or abdomen with injury severity score >25
Hypotension with systolic blood pressure <90 mmHg at presentation
Sewage or organic contamination/farmyard injuries
Peripheral vascular diseases/thromboangiitis obliterans
Drug-dependent diabetes mellitus/connective-tissue disorders/peripheral vasculitis

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and who underwent VSD therapy combined with limited internal and/or external fixation. Two patients were lost to follow-up, while 36 were available for evaluation for 2.5 years (range, 1–4 years). There were 20 men and 16 women, with a mean age of 36.5 years (range, 18–65 years). Motor-vehicle accidents accounted for 20 injuries, domestic accidents for 5, workplace injuries for 10, and industrial accidents for 3. The lower limb was involved in 16 patients and the upper limb in 20. According to the Gustilo and Anderson grading, grade III A was seen in 20 cases and III B in 16 cases. The fracture site was the tibia and fibula in 9 cases, simple tibial fractures in 4 cases, ankle fractures in 3 cases, simple radial fractures in 8 cases, simple ulnar fractures in 6 cases, and radial and ulnar fractures in 6 cases. According to the AO fracture classification, A_2 type was seen in 4 cases, B_3 type in 12 cases, C_1 type in 12 cases, and C_3 type in 8 cases. Wound length was from 11.3 cm to 28.6 cm and width was from 5.7 cm 13.2 cm. Injury to surgery time was 1.5–9.0 h, with an average of 3.8 h. The degrees of skin recovery points were:: excellent (soft skin, subcutaneous induration no obvious sense); benign (skin more soft, loose feeling in the skin induration); and poor (extensive subcutaneous induration) [11]. Descriptive analysis was used to assess the complications, wound healing, infections, and bony union.

Treatment

Treatment was divided into 2 stages. In the first stage, all patients were admitted to the hospital. After emergency anesthesia in the operating room, the wound underwent radical debridement, and was covered by VSD for 5–7 days. Debridement included elimination of ischemic and irreparably damaged tissues, as well as removal of foreign substances and opening of dead space. The fracture was fixed by limited internal and/or external fixation. The wounds were covered with VSD dressing (VSD choice Wuhan Davis Medical Technology Co., Ltd), which was cut according to the shape and size of the wound. The VSD dressing edges were thoroughly tailored to cover the wounds, leaving no dead space [12]. A semi-permeable membrane was attached within 2 cm of the wound fringe, creating an airtight wrap.

In the second stage, after the wound was covered with VSD dressing for 5–7 days, the surgeons removed the VSD under anesthesia in the operating theater. Debridement was repeated, if necessary, from the sclerotic bone with a sharp osteotome until blood oozed to the bone surface, and the deep tissue injuries were repaired if possible. Local flaps and skin grafts were selected to cover the defective skin. In the present study, local flaps were used in 8 cases, cross-leg bridge flaps in 3 cases, abdominal hypodermal vascular net flaps in 5 cases, and split-thickness skin grafts in 10 cases. The donor sites were sutured after flap extractions if feasible. Remaining donor site wounds were covered with split-thickness skin from the scalp, lower limbs, chest, or abdomen.

Postoperative management

The VSD postoperative dressing silicone tube was connected to a negative pressure maintained at –125/–400 mm Hg (1 mm Hg=0.133 kPa), because excessive vacuum pressure may restrict the blood supply and lead to hypoproteinemia from over-exudation. VSD dressing was examined every day to prevent leakage. Broad-spectrum antibiotics were administered for any wounds that had local tissue necrosis and infection. Local flaps and skin grafts were selected, and anti-inflammatory, anti-convulsive, and anti-coagulant medications were routinely administered. Nutritional support, supportive care, and management of complications were provided as necessary. Early postoperative active and passive rehabilitation exercises were advocated. Sedatives and analgesics were administered to prevent vasospasm caused by various stimuli.

Results

The mean follow-up duration was 2.5 years (range, 1–4 years). Of the 36 patients, 31 (86.1%) had an excellent outcome, 2 (5.5%) had a good outcome, and 3 (8.3%) had a poor outcome [13]. Of the 16 injuries to the upper limb, 14 (87.5%) had an excellent outcome. Of the 20 injuries to the lower limb, 17 (85.0%) had an excellent outcome (Figures 1–3).

Complications

At the final follow-up, 5 out of 36 patients had complications, with 1 case of type-A and 1 case of type-B infection alone, 1 case of type-B with delayed union or nonunion, 1 case of type-B with infection and delayed union, and 1 case of wound necrosis, infection, and nonunion.

Wound healing

Wound healing was assessed as type A in 30 injuries (82%), type B in 5 (15%), type C in 3 (1%), and type D in 1 (2%). Complications in wound healing requiring surgical intervention occurred in 4 patients (11.1%), of which a lower limb was involved in 3 patients and an upper limb in 1 patient. Marginal necrosis of flaps requiring redebridement and secondary suturing was found in 3 patients, and marginal necrosis of flaps requiring debridement and skin graft cover in 1 patient. While 4 of these wounds eventually healed, 1 patient with a tibia and fibula fracture had persistent deep infection, osteomyelitis, and a persistent sinus for 3 years before it closed. This patient had a nonunion, opted to be mobilized with a brace, and refused any further surgery.

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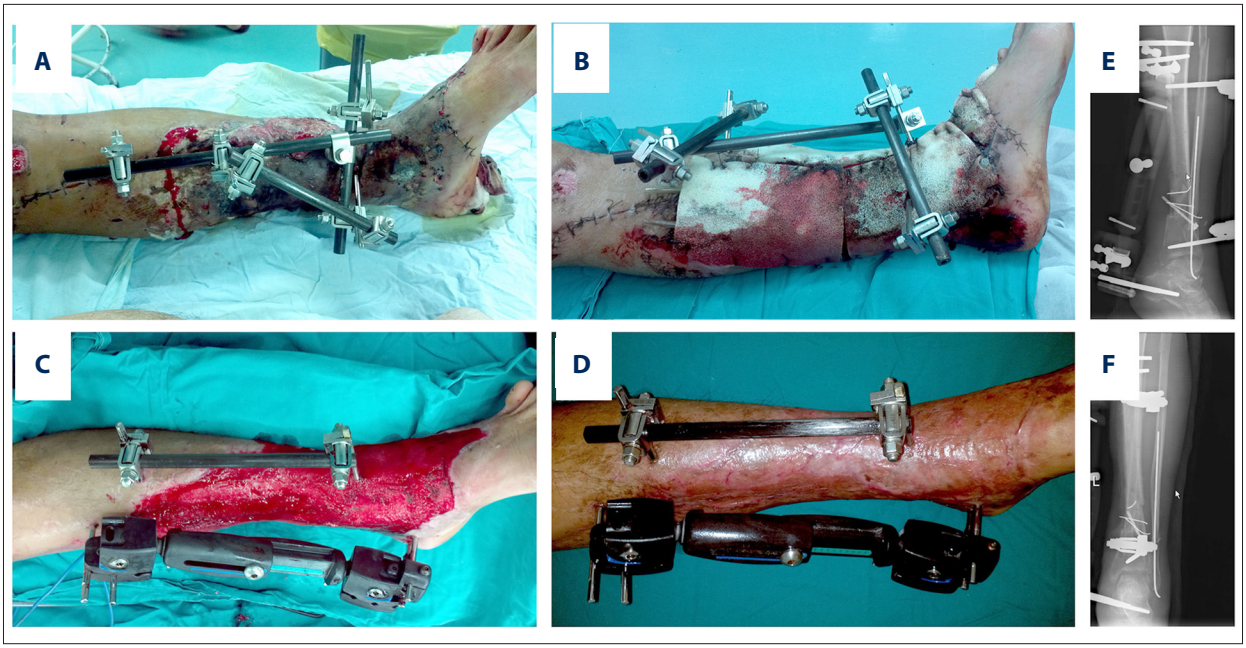

Figure 1. Case 1. Photographs showing a type-III B open fracture of the lower third of tibia and fibula with a wound length of 28.6 cm and width was 10.7 cm on the anteromedial aspect of the leg. (**A**) The wound was debrided and covered with VSD dressing, (**B**) At the time of final VSD dressing, (**C**) Replacement of the VSD dressing 3 times, (**D**) The wound was managed by skin grafts with an excellent outcome, (**E**) Radiographs showing tibia and fibula fracture achieved primary union (**E**) and (**F**).

Infection

Infection was observed in 4 out of 36 patients (11.1%). It was superficial in 2 (5.5%) patients and resolved after redebridement, VSD change, and treatment with intravenous antibiotics. The other 2 (5.4%) patients had deep infection (Table 2). Debridement was performed every week, VSD was regularly changed 2–6 times, and intravenous antibiotics were administered. One of these patients also required revision with removal of the implant, adjustment of external fixation, and a transposition flap. This resulted in an infected nonunion and sinus for 3 years. During this period, the patient was mobilized with a brace and declined further treatment of the nonunion. The other patient refused further treatment and opted to be mobilized with a brace. No infection occurred in injuries of the upper limb.

Bony union

In total, 46 of the 51 (90.2%) fractures had uneventful union. Delayed union was observed in 2 patients (5.5%), which progressed to union without any open interventional procedure, and with adjusted external fixation, if necessary. However, these patients required functional cast bracing before the fracture was clinically healed. One patient (2.7%) had nonunion, which required secondary intervention and revision of the fixation.

Discussion

Gustilo and Anderson grade III injury, which is often a high-energy injury associated with segmental bone and extensive soft-tissue defects, requires complex reconstruction. In treatment of Gustilo and Anderson grade III B injury, maintenance of fracture fixation, reduction of infection rates, and early exercise are clinically difficult. However, the wound healing rate and functional rehabilitation in these injuries have dramatically improved in recent years with the advent of many new methods, adequate debridement, microsurgical techniques, and copious irrigation [14,15].

Several reports have suggested that the treatment of Gustilo and Anderson grade III B injury would be meaningful only when factors such as the incidence of wound infection, delayed union, and amputation were considered. Many surgeons recommend a definitive bony and soft-tissue reconstruction within the critical period of the first 72 h. This may be impossible in many patients due to complex traumatic extremity, such as segmental bone, extensive soft-tissue defects, wound contamination. In a prospective study of 326 open fractures, Gustilo and Anderson [16] reported that 8 patients developed infection, of which 5 were acquired in the hospital. They concluded that "During the long intervals when such wounds are open, secondary infection, usually with Gram-negative organisms, may be a problem since these organisms are usually difficult to control by antibiotics alone."

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Figure 2. Case 2. Photographs showing a type-III B open fracture of the radius with a wound length of 11 cm and width of 6 cm; length was 6 cm and width was 4 cm on the anteromedial and back aspects of the arm, respectively. (A, B) The wound was debrided and covered with VSD dressing. The fracture was fixed with limited internal and external fixation, and (**C, D**) the wound was managed by skin grafts with an excellent outcome.

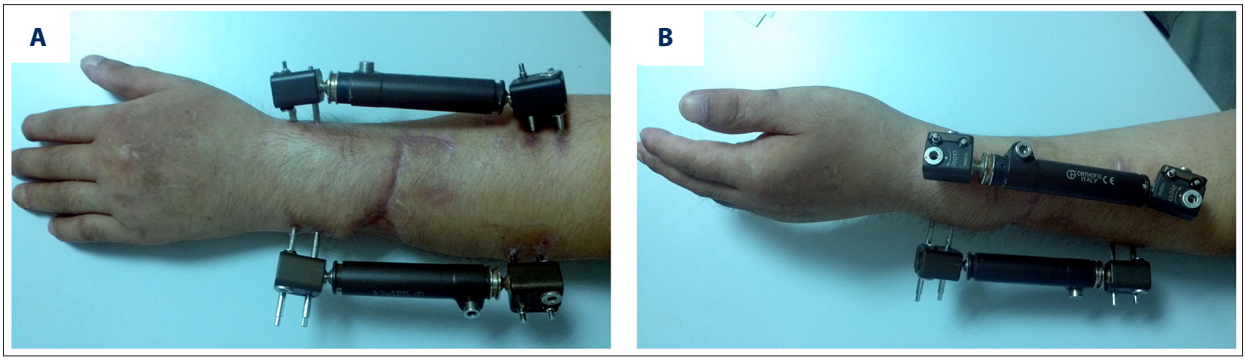

Figure 3. Case 3. Photographs showing a type-III B open fracture of the radius and ulna with a wound area of length 8 cm and width of 6 cm on the anteromedial aspect of the arm. The fractures were fixed with limited internal and external fixation. The wound was managed by skin grafts, with an excellent outcome (**A, B**).

Our primary aim was to demonstrate the advantages of selective VSD technique combined with limited internal and/or external fixation of Gustilo and Anderson grade III injuries, and also to verify the indications that evolved from the experiences of orthopedic surgeons. The results of this retrospectively study have shown that these indications are appropriate

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Table 2. Details of four patients with infection.

Case	Region	Infective organism	Initial management	Time of infection presentation	VSD times	Secondary procedures	Course of infection
1	Middle third of tibia and fibula	*Bacillus coli*	External fixation	1	2	Debridement, free skin graft, antibiotics	Union delayed until 20 weeks
2	Lower third of tibia	*Bacillus coli*	Internal and external fixation	3	3	Debridement, local transposition flap, antibiotics	Union delayed until 36 weeks
3	Lower third of femur	*Bacillus coli*	Internal and external fixation	1	5	Debridement, local transposition flap, antibiotics	Union delayed until 40 weeks
4	Lower third of tibia and fibula	*Pseudomonas aeruginosa*	Internal and external fixation	3	6	Debridement, local transposition flap, antibiotics	Persistent infective nonunion, mobilized

and can be used as guidelines for undertaking the VSD technique combined with limited internal and/or external fixation for the treatment of Gustilo and Anderson grade III B injury. With only minor alterations, these guidelines were as follow:

1. Adequate debridement

Adequate debridement remains a difficult surgical problem. If there is the slightest doubt as to whether there has been adequate debridement of the wound after an open fracture, the wound should not be closed, regardless of the type of open fracture. For the surgeon who manages only an occasional open fracture, the safe rule is to not close the wound. Scully et al. described the criteria for muscle viability, termed as the 4 C's: (1) color, (2) capacity to bleed, (3) contractility, and (4) consistency. In our experience, color was a reliable guide and the other 3 C's correlated well with muscle viability. The presence of bleeding from the wound margins, which could be apposed without tension, was found to be more important.

2. Limited internal and/or external fixation

Limited internal and/or external fixation for the treatment of Gustilo and Anderson grade III B injury has the following advantages [17]: (1) limited internal fracture fixation helps to position on the line and stability; (2) the operation is simple, safe, and when the entire complex fractures without excessive expansion of the wound, internal fixation is extremely limited to favor wound and bone healing; (3) external fixation helps to better reset the tendons, ligaments, fractures and soft-tissue (i.e., ligament plasty effects); and (4) fixed and reliable stability for early functional exercise stimulates callus growth and improves the quality of fracture healing.

3. Application of the VSD technique

VSD is widely used for wound restoration in orthopedic surgeries [2,9,10,12,13]. The exact mechanism by which vacuum-assisted technology promotes wound healing remains unclear [9]. Studies suggest that vacuum facilitates early healing of the diseased tissue by reducing swelling, improving local microcirculation, accelerating metabolism of nutrients towards the diseased tissue, and promoting and stimulating granulation growth. Other studies suggest that the main advantage of vacuum-assisted technology is that it promotes healing of early lesions to provide mechanical strength, which regulates tissue growth; the growth of uninfected granulation tissue on the wound is the key to skin graft survival.

After debridement and VSD covering, granulation tissues on the wound surface developed well in all 36 cases in our study, decreasing the required flap area, providing a better soft-tissue bed for free-flap and skin graft transplantation, and generally improving the success of the second-stage surgery and post-surgical outcome. Notably, in all 4 cases with infection and necrosis in deep tissues, the infection was well controlled by 1–3 debridement-VSD treatment cycles.

Vacuum-assisted technology has been used in clinical practice since 1997, and has significant advantages [5] in the wound overlay. Sixteen patients required replacement of the VSD for 2–6 times (average, 3.2 times). Three patients had local infection, and the wound cultures showed *Pseudomonas aeruginosa*. By appropriately replacing the VSD in a shorter time (4 days), and by debridement and antibiotic-sensitive applications; 1 case of infection was controlled in 2 weeks and another case in 3 weeks. The wound infection rate for Gustilo III B injury was previously reported to be 10–50% [8]. De Franzo covered lower extremity wounds with exposed muscle, tendon, and bone, primarily

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with the VAC system, to subsequently fill the defects with split-thickness skin grafts, or a regional flap rotated into the granulating bed. Stable wound coverage was achieved in 31 of 38 patients in 2 months to 6 years. Mendonca [6] reported 15 cases of ankle and foot ulcers, in which the VSD treatment significantly reduced the wound area to 2–10 cm^2 (average, 7.41 cm^2) and the preoperative to postoperative area to 0–2 cm^2 (average, 1.58 cm^2), with an average reduction of 35.06%.

4. Wound delayed primary closure by skin grafts or flaps

Wound delayed primary closure by skin grafts or flaps could provide surgeons with enough time to design an optimal procedure based on the individual's situation. In addition, it could provide the patients with sufficient time to consult and consider all options, and thus avoid medical disputes [13]. In a recent report on one-stage bone and skin or soft-tissue reconstructions of 61 patients, 10 had associated trauma, besides extremity fractures, of which 3 had potentially life-threatening injuries, such as spinal, brain, or abdominal trauma. Studies often emphasize the importance of 'emergency free flaps' in extremity trauma but provide very little information about the overall trauma severity of the patients [10,12,18–21]. Moreover, deferred microsurgical repair provided the patients with adequate time to receive comprehensive management, and made the surgery less challenging. Importantly, vacuum-assisted technology could provide better vascularity of the reconstructive recipient bed for surgical intervention. In our study, primary closure of all 36 wounds was delayed by skin grafts or flaps, including 8 cases of local flaps, 3 cases of cross-leg bridge flaps, 5 cases of abdominal hypodermal vascular net flaps, and 10 cases of split-thickness skin grafts, which grew well without any complications.

Conclusions

Using VSD before skin grafts or flaps coverage combined with limited internal and/or external fixation is a suitable option for Gustilo and Anderson grade III injury. These techniques could accelerate wound healing, improve graft and flap survival rate, shorten the healing time, and improve patient function.

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