



Application of vac in type III open fractures

VAC in open fracture

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Abstract

Aim: Functional results of patients with Type III open long bone fractures treated with vacuum-assisted closure (VAC) and approximating sutures were evaluated. **Material and Method:** A total of 21 patients (4 female, 17 male with a mean age of 27 years, range: 3–64 years) with Gustilo-Andersen Type 3 open fracture were included in the study. The mean follow-up period was 25.67 months (range, 9–52 months). Thirteen patients had Type IIIB and eight patients had Type IIIC open fractures. Following a large debridement and irrigation in an operating room setting, wound dimensions were measured. Subsequently, VAC was applied. During the application, skin traction sutures were applied over the vacuum sponge. During the last dressing change in which a clean granulation tissue was obtained, the wound was closed following the measurement of its dimensions. Wound dimensions measured during the large debridement in the operating room were compared with the wound dimensions measured after the final VAC application. **Results:** Mean duration between trauma and operation was 7.57 hours (range, 2–23 hours). The wound was closed with delayed primary suturing in seven patients. In the remaining 14 patients, wound dimensions measured following the last VAC application were found to be decreased with a mean of 40.02% (range, 20–60%). Seven patients underwent a skin graft, two had a free flap application, four had a fasciocutaneous flap, and one had a fasciocutaneous flap + graft application. Two patients underwent revision operations for graft failure. Five patients (23.8%) developed a deep wound infection. The infections resulted in osteomyelitis in two patients (9.5%). **Discussion:** VAC application together with skin traction sutures in Type IIIB and C open fractures decreases wound size dimension of a graft or flap to be applied. Also it may reduce the requirement for secondary interventions.

Level of evidence: Level IV.

Keywords

Open Fracture; Vacuum-Assisted Closure; Skin Traction Suture; Wound Closure

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Introduction

Type III open fractures are high-energy injuries and may occur together with neurovascular defects, large soft tissue damage, and bone loss [1]. This in turn directly affects the treatment and clinical results. The risk of infection is higher in contaminated Gustilo-Anderson Type IIIB fractures, which cannot be closed primarily, and in Type IIIC fractures together with vascular injury [2]. Therefore, management of the infection is the main problem in these types of injuries [3]. Commonly, primary wound closure is not possible in these types of fractures. Early flap or graft applications might increase the complication rate including graft failure and infections [4].

Vacuum-assisted closure (VAC) applies negative pressure in open wounds. It was demonstrated that VAC significantly improves wound healing at the micro and macro level [5]. Vacuum-assisted closure contributes to wound healing by stimulating angiogenesis and the formation of granulation tissue in addition to removing fluid and debris in the wound [6]. The VAC procedure is used mostly in chronic wounds. Recently, the use of VAC has been defined for temporary closure of traumatic wounds [7].

The present study evaluates clinical and radiological results of the cases that had undergone temporary closure with VAC during the early period of Type IIIB and C open fractures.

Material and Method

A total of 21 patients (17 males and 4 females with a mean age of 27 years, range 3–64 years) with Type IIIB and C open fractures of long bones who received VAC therapy during the early period of treatment between the years 2011 and 2014 were retrospectively evaluated. Thirteen patients were found to have Type IIIB and eight patients Type IIIC open fractures. Patients with diabetes mellitus, rheumatoid arthritis, and immune compromised conditions were excluded. The mean duration of the follow-up and hospitalization were 25.67 ± 14.36 months (range, 9–52 months) and 30.71 ± 20.84 days (range, 8–75 days), respectively. Demographic data of patients is presented in Table 1.

Patients were evaluated at the emergency service in terms of soft tissue and bone defects, periosteal stripping, major vascular injury, compartment syndrome, and contamination. A computed tomography (CT) angiography was performed for patients who were considered to have vascular injury. Seventeen patients had lower extremity and four patients had upper extremity injuries. Severe additional injuries were present in eight cases (additional injuries: fracture of the left femur neck, a bilateral cruris fracture and a left distal humerus fracture in one case; a multiple fracture of the left foot in one case; the fracture of right femur diaphysis in one case; a thoracic injury in one case (gunshot wound); a patellar tendon rupture and a defect in one case; a head trauma in one case; pneumothorax in one case; a tibia diaphysis fracture and bimalleolar fracture in the ankle joint in one case). Fractures were classified according to the Gustilo-Anderson classification.

Soft tissue and bone that had lost vitality were debrided and irrigated. Following percutaneous pinning or external fixation, the wound was closed using VAC (Confort NPWT C300, Konfort Özel Sağlık Hizmetleri Tıbbi Malzemeler Sanayi ve Ticaret LTD. ŞTİ.,

Eskisehir, Turkey). Major neurovascular structures must not be in contact with the vacuum area so that they are not directly affected by the negative pressure. When necessary, muscle flaps were used to cover and protect these structures. When it was impossible to cover the bone structures, a vacuum sponge was applied directly over the bone. A sponge was cautiously placed into the wound to fill it completely, taking care not to go out of the wound to avoid squeezing the tissue. In order to decrease the size of the wound and facilitate delayed primary or secondary closure, skin traction sutures were applied over the vacuum sponge (Figure 1). A VAC device was programmed to apply a continuous negative pressure of 100–125 mmHg and 130–160 mmHg in the upper and lower extremities, respectively. The VAC application was repeated as necessary at 48–72-hour intervals, along with debridement and irrigation.

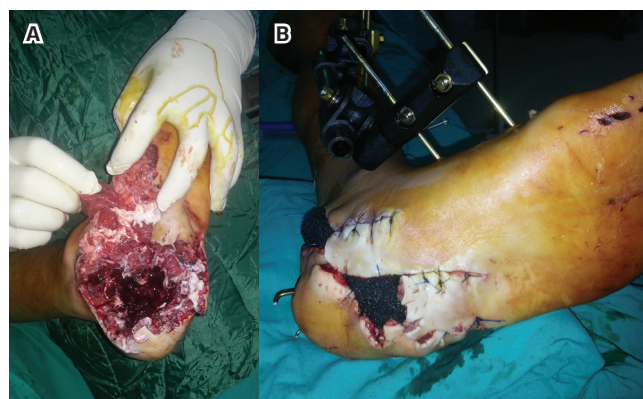


Figure 1. Appearance of the wound following initial debridement in a patient with an open fracture of the calcaneus due to a gunshot wound (A). VAC application together with skin traction sutures and shrinkage of the wound (B).

For antibiotic prophylaxis, cefazolin 1 g was administered every eight hours, once a day after the wound was closed and gentamicin 80 mg was applied for five days every 12 hours. Antibiotic treatment was adjusted in cases that developed an infection, according to the culture and antibiogram results. Delayed primary closure was applied when a clean granulation tissue was achieved and the wound could be primarily closed; secondary closure with a graft and/or flap application was performed on the remainder of the cases.

Wound dimensions were evaluated using the wound dimensions after the first debridement and following the last VAC application. In addition, rates of infection, fracture union (at least three cortex continuity of bridging callus in the anteroposterior and lateral radiographs), duration of application of VAC, and the association of duration of VAC with the development of complications were evaluated.

Statistical analysis was performed using SPSS for Windows 18.0 (SPSS Inc, Chicago, IL, USA) program. Student's t test and Mann-Whitney U test were used in the evaluation of parametric and nonparametric variables, respectively. Categorical data were compared using a chi-square test. $P < 0.05$ was accepted as statistically significant.

Results

The mean time between the trauma and first debridement was 7.57 hours (range, 2–23). Osteosynthesis was obtained with external fixator ($n=13$), percutaneous pinning ($n=3$), EF+ percuta-

Table 1. Patient Information

	Gender	Age	Trauma	Type of open fracture	Fracture	Neurovascular deficit	Initial surgery	Duration of VAC (day)	Skin suturing	Infection	Duration of union (month)	Dimensions of initial wound (cm)	Decreasing in wound dimension (%)
1	M	54	GSW	3B	Multiple fracture and dislocation of foot	-	Percutaneous pinning	8	Free flap	Staphylococcus Haemolyticus	6	10X8	40
2	M	30	Traffic Accident	3B	Femur Neck + Femur Diaphysis	-	EF	8	Fasciocutaneous flap	Acinetobacter Baumannii	8	35X25	30
3	F	64	GSW	3B	Radius+Ulna Diaphysis	-	EF	8	Delayed primary closure	-	4	15X10	Closed
4	M	27	Traffic Accident	3B	Distal Humerus	-	EF+ Percutaneous pinning	8	Delayed primary closure	-	4	12X8	Closed
5	M	28	GSW	3B	Proximal Tibia + Tibia Diaphysis + Fibula Diaphysis	-	EF	5	Fasciocutaneous flap + graft (failure)	Klebsiella Pneumoniae (Osteomyelitis)	Pseudoarthrosis	22X12	30
6	M	31	GSW	3C	Supracondylar Femur	Popliteal Artery	EF	16	Graft	-	5	23X13	40
7	M	37	Mine	3B	Left Tibia+Fibula Diaphysis	-	EF	12	Graft	-	7	12X6	40
8	M	32	GSW	3C	Tibia Fibula Distal End	Tibialis anterior + peroneal nerve	EF	4	Free flap (failure)	-	4	20X10	50
9	M	12	Traffic Accident	3B	Tibia Diaphysis fracture	-	EF	7	Fasciocutaneous flap	No growth (Osteomyelitis)	Pseudoarthrosis	15X8	30
10	M	28	GSW	3B	Tibia Diaphysis	-	EF	6	Delayed primary closure	-	6	7X5	Closed
11	M	31	GSW	3C	Ulna Diaphysis	Ulnar artery	EF	3	Delayed primary closure	-	4	10X4	Closed
12	M	29	GSW	3B	Proximal Tibia + Fibula Diaphysis	-	EF	7	Graft	-	3	13X9	30
13	M	18	Traffic Accident	3C	Femur Diaphysis	Femoral artery Sciatic nerve	EF	17	Graft	-	4	30X25	40
14	M	20	Mine	3C	Fibula Distal + Medial Malleolus	Dorsalis pedis	EF+ Percutaneous pinning	8	Graft	-	3	20X15	20
15	M	27	GSW	3B	Calcaneus	-	Conservative (splint)	7	Delayed primary closure	-	3	10X4	Closed
16	M	19	GSW	3C	Calcaneus	Tibialis posterior	EF+ Percutaneous pinning	16	Fasciocutaneous flap	-	3	15X10	50
17	F	35	GSW	3B	Iliac Wing	-	Conservative	6	Delayed primary closure	-	3	5X4	Closed
18	M	9	Traffic Accident	3B	Medial Cuneiform	-	Conservative (splint)	5	Graft	-	4	12X4	50
19	F	3	Traffic Accident	3C	Multiple fractures of foot and ankle	Dorsalis pedis	Percutaneous pinning	5	Fasciocutaneous flap	-	3	23X12	60
20	F	17	Farming	3C	Distal Humerus + Radius Diaphysis	Brachial artery + radial nerve	EF	7	Graft	Pseudomonas Aeruginosa (Humerus)	5	22X14	50
21	M	17	Traffic Accident	3B	Femur Diaphysis	-	EF	7	Delayed primary closure	-	4	30X15	Closed

EF: external fixator, GSW: Gunshot wound, VAC: Vacuum-assisted closure

neous pinning (n=3), and conservative treatment (n=3). For the second surgical intervention for fracture, plaque and screw, EF, and intramedullary nail fixation were used in eight, three, and two patients, respectively. Mean time to union was 4.34±1.47 months (range, 3–8 months).

The mean duration of VAC application was eight days (range, 3–16). A delayed wound closure was performed in seven patients (Figure 2). In the remaining 14 patients, mean decrease in the wound dimensions between pre and post-VAC application was found to be 40.02% (range, 20–60%). Those patients

underwent skin grafting (n=7), fasciocutaneous flap (n=4), free flaps (n=2), or fasciocutaneous flap + graft (n=1). Two patients who developed graft failure underwent revision surgery.

No statistically significant difference was found in terms of duration of union between the patients who underwent delayed primary wound closure compared to those who underwent secondary wound closure (Table 2). The dimensions of the wound following the first debridement was greater in patients who underwent secondary closure and the difference was statistically significant when compared with the dimensions of the wounds

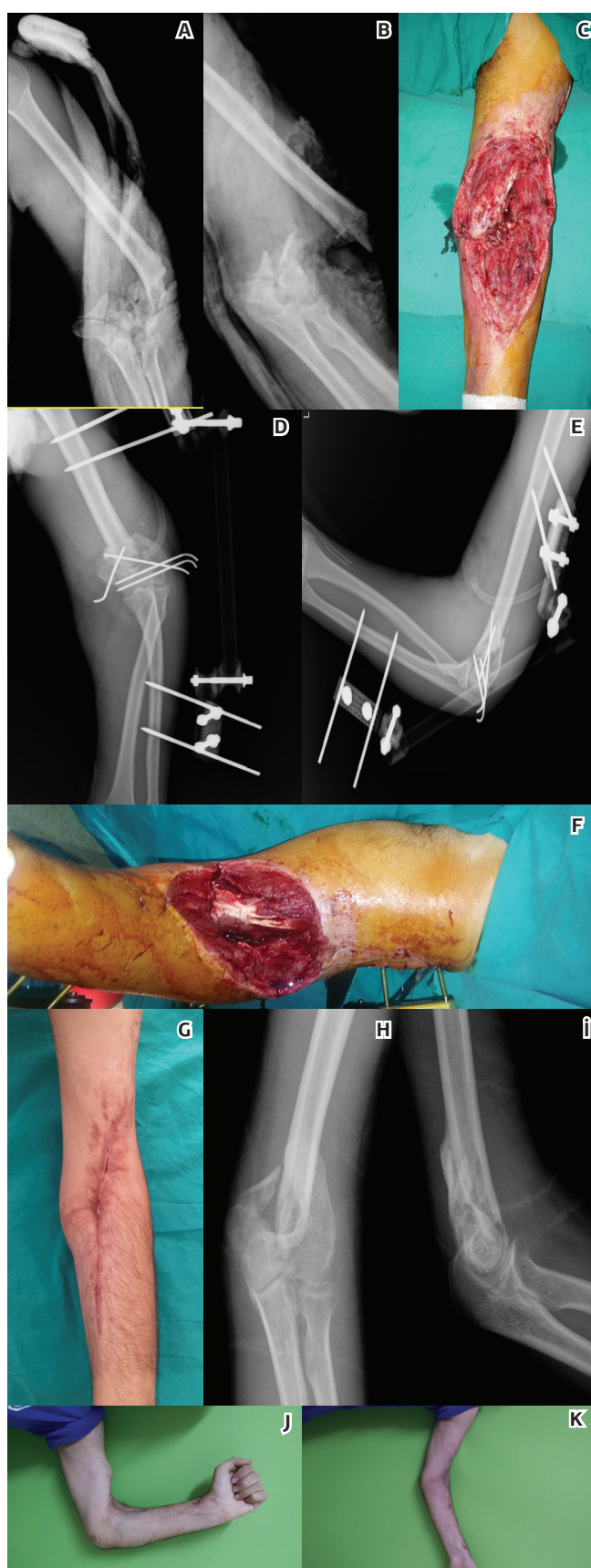


Figure 2. AP direct X-ray obtained in the emergency department of a patient with Type IIIB open distal humerus fracture due to a traffic accident (A). Lateral direct X-ray obtained in the emergency department of the patient (B). Picture taken during the initial debridement (C). Postoperative AP radiograph of the patient who underwent external fixation + K wire application (D). Postoperative lateral radiograph of the patient (E). Shrinkage of the wound dimensions during VAC change (F). Appearance of the wound 1 month after the injury (G). Anteroposterior and lateral radiographs taken 4 months after the injury (H, I). Elbow flexion and extension 4 months after the injury (J,K).

of patients who underwent delayed primary closure (P=0.031). Delayed primary closure was applied to six out of thirteen patients with Type IIIB open fractures (46.2%) and one out of eight patients with Type IIIC open fractures (12.5%). No significant difference was detected between Type IIIB and C cases in terms of necessity for delayed primary closure.

A deep infection developed in five (35.7%) out of fourteen patients who underwent secondary closure, of whom two patients (14.2%) developed osteomyelitis. None of the patients who underwent delayed primary closure (n=7) developed an infection (Table 3). Statistically significant difference was found between the primary and secondary closure in terms of deep infection (p=0.028). The microorganisms that caused infection were *pseudomonas aeruginosa*, *acinetobacter baumannii*, *staphylococcus haemolyticus*, and *klebsiella pneumoniae*. However, no microorganism could be isolated in one patient. The infection was treated through debridement and antibiotherapy in those patients. However one patient developed osteomyelitis refused further intervention. No statistically significant association was found between the dimensions of the first wound and development of infection (p=NS). No significant association was found between the development of infection and the duration of VAC application (p=NS). Trauma type and first treatment applied had no association with the development of an infection either. The duration of union was found to be significantly longer in patients who developed an infection (p=0.021). Pseudoarthrosis and osteomyelitis developed in two patients. In those patients debridement, antibiotherapy, and EF were performed. Union was achieved at the 19th month in one patient. However, in the other patient union could not be achieved. This patient refused further surgical intervention after a follow-up of 34 months.

Table 2. Comparison of closure techniques

	Delayed primary closure (n=7)	Secondary closure (n=14)	P
Age (year±sd)	32.71 ± 5.60	24.92 ± 3.91	NS
Time between trauma-initial debridement (hour±sd)	3.71 ± 0.56	9.42 ± 2.09	P=0.007
Duration of VAC (day±sd)	6.43 ± 0.65	9.42 ± 1.34	NS
Duration of union (month±±)	3.93 ± 0.38	4.58 ± 0.48	NS
Initial wound dimensions (cm ²)(range)	118.71(20-450)	275.93 (48-275)	P=0.031
Shrinkage (%) (range)	100	40.02 (20-60)	p=0.001

NS: Non significant, VAC: Vacuum-assisted closure

Table 3. Comparison of patients by development of infection

	No infection (n=16)	With infection (n=5)	P
Age (year)	26.69 ± 3.41	33.67 ± 10.84	NS
Time between trauma-initial debridement (hour±sd)	7.50 ± 1.68	6.33 ± 2.96	NS
Duration of VAC (day±sd)	8.66 ± 1.10	7.67 ± 0.33	NS
Duration of union (month±sd)	3.97 ± 0.29	6.33 ± 0.88	P=0.021
Initial wound dimensions (cm ²)(range)	190.66 (20-750)	329.40 (80-875)	NS

NS: Non significant, VAC: Vacuum-assisted closure

Discussion

The degree of soft tissue injury determines the treatment of Type III open fractures. If a wound cannot be closed primarily, a high risk of infection is the surgeon's major concern [8]. Delayed primary closure or secondary closure with graft/flap may take a long time, possibly increasing the risk of infection [9].

The best way to decrease the risk of infection in open wounds is to remove tissues that are already infected or might provide a basis for infection with serial debridement. In this way the growth of bacteria in a medium of impaired blood flow could be prevented. VAC can be applied in those wounds to increase the efficacy of debridement. VAC is a safe technique for wound closure that can be applied easily in such types of complex wounds [10]. It provides for the removal of interstitial fluid and debris through negative pressure. Thus, contaminated tissue fluid is removed from the fracture site during the period between the dressing changes and bacterial density in the tissue can be decreased [11]. Also, local blood flow is increased and oxygenation of the wound is provided [12]. VAC decreases the size of wounds that are difficult to close and provides an appropriate situation for secondary wound closure methods. In defects in the regions of weak soft tissue reserves such as the cruris, foot, and around the joints, good blood flow to the granulation tissue increases the success of grafts and flaps. Also, VAC increases cellular proliferation, angiogenesis, and microvascular blood flow and thus decreases edema and chronic inflammation, thereby increasing the success rate of grafts and contributing positively to wound healing [13]. VAC has been demonstrated to increase some molecules and the expression of some cytokines with anabolic activity such as intracellular adhesion molecule-1 (MIF), vascular endothelial growth factor (VEGF), main fibroblast growth factor, and type 1 collagen, thus decreasing the duration of wound healing and increasing the quality of healing [14]. In conclusion, VAC applications not only increase the efficacy of debridement but also prevent the contact of the open wound with the external environment. Moreover, the number of daily dressing changes, which are a misery for the patient, are decreased.

Kilic et al. [15], applied VAC in the treatment of open wounds. They showed that VAC application decreases the duration of hospital stay and reduces the rate of infection and treatment costs. Stannard et al. [16] reported that the infection rate in their patients who received VAC was five times lower compared to the control group. In addition, with the closed circuit obstacle, bacteria that are present in the contaminated area are prevented from being transmitted to other patients and healthcare personnel in terms of hospital infections. Another advantage of VAC is that it prevents the open wound from being contaminated by microorganisms of hospital origin. It is known that most of the pathogens that infect open wounds are not from the first trauma environment but through the hospital environment [17]. The VAC method, which was first applied to chronic wounds during the initial treatment, has also begun to be used safely in acute injuries. Govaert et al. [18] treated a pelvic fracture complicated by urogenital contamination. Hou et al. [19] reported that VAC decreased the duration of wound healing in 32 patients with Type III open tibial fracture and that application of local rotational flap was adequate in most patients and that VAC decreased the need for free flap procedures. However, they

also reported that negative effects of the procedure such as that rates of amputation and infection were increased when the duration of the VAC procedure exceeded a week. Concerns regarding long durations of VAC application were also reported by other researchers [20]. The mean duration of VAC in patients with and without development of infection in this present study was 7.67 ± 0.33 days and 8.66 ± 1.10 days, respectively. We found no significant association between the duration of VAC application and development of complications.

In another study, Ulusal et al. [21] reported a significant decrease in the wound dimensions with the use of VAC. In the present study, we also observed decreased wound dimensions in patients treated with VAC. In seven patients the wounds were closed with delayed primary repair. We performed efficient skin traction over the sponge following VAC application and sponge placement. We augmented the effect of the procedure to reduce the wound size. The dimensions of grafts or flaps required for the closure of the shrinking wounds are naturally decreased, which decreases the donor site morbidity. In addition, the duration of surgical procedure is decreased and the procedure is made easier.

Conclusion

VAC application together with approximating sutures increases the comfort of the patient by decreasing the number of required daily dressing changes, decreases the necessity of secondary interventions by decreasing the wound dimensions, and decreases the donor site morbidity by decreasing the graft dimensions when the wound is required to be closed secondarily.

Ethical Statement

All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

Scientific Responsibility Statement

The authors declare that they are responsible for the article's scientific content including study design, data collection, analysis and interpretation, writing, some of the main line, or all of the preparation and scientific review of the contents and approval of the final version of the article.

Animal and human rights statement

All procedures performed in this study were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards. No animal or human studies were carried out by the authors for this article.

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Conflict of interest

None of the authors received any type of financial support that could be considered potential conflict of interest regarding the manuscript or its submission.

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