Original Article

Negative pressure wound therapy for Gustilo Anderson grade IIIb open tibial fractures

Chul Hyun Park, Oog Jin Shon, Gi Beom Kim

Abstract

Background: Traditionally, Gustilo Anderson grade IIIb open tibial fractures have been treated by initial wide wound debridement, stabilization of fracture with external fixation, and delayed wound closure. The purpose of this study is to evaluate the clinical and radiological results of staged treatment using negative pressure wound therapy (NPWT) for Gustilo Anderson grade IIIb open tibial fractures.

Materials and Methods: 15 patients with Gustilo Anderson grade IIIb open tibial fractures, treated using staged protocol by a single surgeon between January 2007 and December 2011 were reviewed in this retrospective study. The clinical results were assessed using a Puno scoring system for severe open fractures of the tibia at the last followup. The range of motion (ROM) of the knee and ankle joints and postoperative complication were evaluated at the last followup. The radiographic results were assessed using time to bone union, coronal and sagittal angulations and a shortening at the last followup.

Results: The mean score of Puno scoring system was 87.4 (range 67–94). The mean ROM of the knee and ankle joints was 121.3° (range 90°–130°) and 37.7° (range 15°–50°), respectively. Bone union developed in all patients and the mean time to union was 25.3 weeks (range 16–42 weeks). The mean coronal angulation was 2.1° (range 0–4°) and sagittal was 2.7° (range 1–4°). The mean shortening was 4.1 mm (range 0–8 mm). Three patients had partial flap necrosis and 1 patient had total flap necrosis. There was no superficial and deep wound infection.

Conclusion: Staged treatment using NPWT decreased the risks of infection and requirement of flap surgeries in Gustilo Anderson grade IIIb open tibial fractures. Therefore, staged treatment using NPWT could be a useful treatment option for Gustilo Anderson grade IIIb open tibial fractures.

Key words: Gustilo Anderson grade IIIb open fractures, negative pressure wound therapy, staged protocol, tibia

MeSH terms: Tibial fractures, wound infection, open fractures, wound healing

Introduction

Traditionally, Gustilo Anderson grade IIIb open tibial fractures have been treated by initial wide wound debridement, stabilization of fracture with external fixation, and delayed wound closure.[1] However, several complications such as deep infection, malunion and nonunion have been reported after treatment using traditional protocol.[2-4] Early soft tissue coverage for the open wound is currently emphasized because prolonged open wounds increase the risk of postoperative infection.[5,6] Several authors reported that early intramedullary nailing and soft tissue reconstruction yielded faster union times and lower infection rate for the treatment of severe open fracture of the tibia.[7,8]

However, risk of flap failure would be high if soft tissue coverage is performed when soft tissue condition does not stabilize. Occasionally, early soft tissue coverage cannot be performed because the patient's general condition is poor. Moreover, early fixation using intramedullary nailing

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risks whole intramedullary infection. Therefore, recently staged management using temporary external fixation was introduced in the treatment of open tibial fractures with some authors reporting good results.[9,10] However, to the best of our knowledge, no study has reported the outcomes of treatment using a staged treatment protocol for Gustilo Anderson grade IIIb open tibial fractures.

The authors used a staged protocol for the treatment of Gustilo Anderson grade IIIb open tibial fractures involving wound lavage, debridement, external fixation, and negative pressure wound therapy (NPWT) within 24 h after hospitalization, followed by a skin graft and flap surgery for soft tissue coverage. This study was performed to evaluate the clinical and radiological results of the treatment using this protocol for Gustilo Anderson grade IIIb open tibial fractures.

Materials and Methods

17 patients with open tibial fracture of Gustilo Anderson grade IIIb and IIIc[3] were consecutively treated using staged protocol by a single surgeon between January 2007 and December 2011. The inclusion criteria were open fractures (Gustilo Anderson grade IIIb), surgical treatment of the fracture by a single surgeon and adult patients 18-year-old or more than 18 years. The exclusion criteria included followup <1 year after the most recent surgery and patients with vascular injury, severe head injury or spinal cord injury. One patient with Gustilo Anderson grade IIIc was excluded from the study as a way to decrease the number of variables. One patient with severe head injury was also excluded from this study. The remaining 15 patients were included in this study. This study was approved by the Institutional Review Board of our hospital, and informed consents were obtained from all cases prior to the surgical treatment.

There were 11 males and four females and the mean age was 59.5 years (range 38–85 years). Mean followup period was 13.3 months (range 12–20 months). The causes of injury were pedestrian accidents ($n = 6$), motorcycle crashes ($n = 4$), motor vehicle accidents ($n = 2$), and falls ($n = 3$). According to the AO/OTA classification,[11] there were one 42-B3, four 42-C2, two 42-C3, two 43-A2, and six 43-A3 fractures [Table 1].

Treatment protocol

Surgical treatment was performed using two or three stages, and treatment protocol of each patient is demonstrated in Table 2. At stage 1 surgical treatment, wound irrigation and debridement were performed within 24 h. The mean duration between trauma and initial treatment was 16.4 h (range 3–23 h). A temporary ankle spanning external fixator (EF) (Artifix, Taeyeon Medical, Incheon, Korea) and a VAC device (Kinetic Concepts Inc., San Antonio, TX, USA) were applied. As an EF, either a mono frame ($n = 5$) or a delta frame ($n = 10$) was used. Fibular fracture had occurred patients; in 5 intramedullary nailing using a rush pin was performed in 2 patients and open reduction and internal fixation using plate were performed patients in 3.

When soft tissue swelling sufficiently decreased and there was no sign of infection, stage 2 surgical treatment was performed [Figure 1]. The mean duration between stage 1 and stage 2 treatments was 16.7 days (range 7–49 days). In all patients, definite fixation of fracture site was performed using minimally invasive percutaneous osteosynthesis (MIPO) with locking plate. The plates for the MIPO varied by the fracture pattern: (1) 3.5-mm periarticular locking distal lateral tibial plate (Zimmer, Cowpens, SC, USA), (2) 5.0-mm locking compression plate (LCP) proximal lateral tibia plate, (3) 3.5-mm LCP

Table 1: Patient demographic data

Cases	Age/sex	OTA classification	G-A classification	Mechanism of injury	NISS	Location of wound
1	59/male	42-B3	IIIb	Fall down	16	Anteromedial
2	53/male	42-C2	IIIb	PA	77	Medial
3	58/male	42-C2	IIIb	MVA	24	Anteromedial
4	48/male	42-C3	IIIb	PA	16	Anterior
5	64/male	42-C3	IIIb	Fall down	16	Anteromedial
6	74/female	42-C2	IIIb	PA	20	Anteromedial
7	56/male	43-A2	IIIb	MVA	29	Circumferential
8	38/female	43-A3	IIIb	PA	24	Medial
9	68/male	43-A3	IIIb	PA	41	Medial
10	49/male	43-A3	IIIb	MVA	17	Anteromedial
11	67/male	43-A2	IIIb	MCA	29	Anterior
12	85/female	43-A3	IIIb	Fall down	24	Anteromedial
13	44/male	43-A3	IIIb	MCA	16	Circumferential
14	61/male	42-C2	IIIb	PA	24	Circumferential
15	68/female	43-A3	IIIb	MCA	24	Medial

OTA=Orthopedic Trauma Association, G–A=Gustilo–Anderson, NISS=New Injury Severity Score, PA=Pedestrian accident, MVA=Motor vehicle accident, MCA=Motor cycle accident

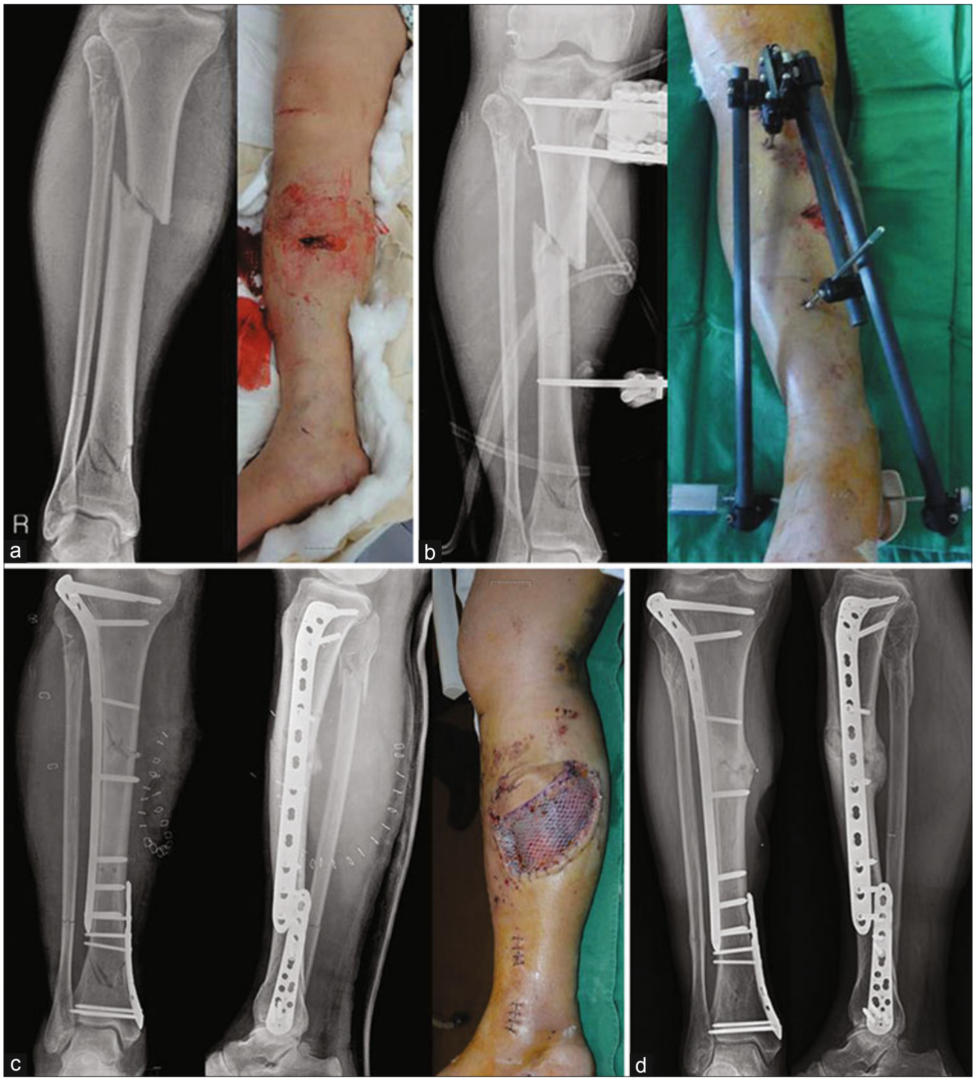

Figure 1: (a) X-ray anteroposterior view of leg bones and clinical photograph showing a right segmental tibio-fibular open fracture (AO/OTA: 42-C2, Gustilo–Anderson: IIIb). (b) X-ray anteroposterior view of leg bones and clinical photograph after wound irrigation and debridement showing a fracture was stabilized using a temporary ankle-spanning external fixator. (c) X-ray anteroposterior and lateral views and clinical photograph showing anterolateral minimally invasive percutaneous osteosynthesis using locking compression plate proximal lateral tibial plate and medial minimally invasive percutaneous osteosynthesis using locking compression plate distal medial tibial plate were performed at 1 week after initial treatment. Soft tissue coverage was performed using local transposition flap and meshed skin graft. (d) Anteroposterior and lateral radiograph of leg bones (at 21 months followup) showing a healed tibia without complication

low bend distal medial tibia plate and (4) 4.5-mm narrow LCP plate (Synthes, Paoli, PA, USA). After fixation, soft tissue reconstruction was performed simultaneously and the method of soft tissue reconstruction was determined according to the anatomy and size of the injury to the soft tissue [Table 2].

When bone healing progression was not observed for 10–12 weeks after definite fixation in fractures with a severe bone defect, bone stimulating procedures such as autogenous bone grafting and bone transport technique were performed early as stage 3 treatment. Stage 3 treatment was performed in 7 patients, and mean duration between stage 2 and 3 treatment was 13.6 weeks (range 10–13 weeks). Autogenous iliac bone grafting was performed in 5 patients, and autogenous iliac bone grafting with demineralized bone matrix (Grafton DBM Putty: 5 mL, Ostothch Inc., Eatontown, NJ, USA) was performed in 1 patient. In 1 patient with severe metaphyseal bone defect, bone transportation was performed [Figure 2].

A long leg splint was applied in the neutral position for 1 week postoperatively. Ankle and knee joint exercises were started 1 week after surgery. Partial weight bearing was allowed from 6 to 8 weeks after surgery for all patients except 1 patient with severe metaphyseal bone defect. Full weight bearing was allowed when there was

Table 2: Staged surgical treatments

Cases	Stage 1			Stage 2			Stage 3	
	Interval 1 (h)*	Fibular fixation	EF type	Interval 2 (days)†	Using devices	Soft tissue coverage	Interval 3 (weeks)‡	Bone stimulating procedure
1	8.5	Plate	Delta	17	Periarticular plate	ALTF	15	Autograft + DBM
2	16.5	-	Mono	18	Narrow LCP	LTF	-	-
3	9.5	Rush pin	Mono	15	Periarticular plate	ALTF	-	-
4	18.5	-	Mono	14	Periarticular plate	SF	13	Autograft + BT
5	19	-	Mono	7	Periarticular plate	LTF	15	Autograft
6	19.8	Plate	Delta	17	Periarticular plate	LTF	-	-
7	3	-	Delta	7	Periarticular plate	ALTF, GF, LTF	14	Autograft
8	23	-	Delta	14	Periarticular plate	ALTF	-	-
9	16.5	-	Delta	7	Periarticular plate	ALTF, LAF	16	Autograft
10	17.2	-	Delta	12	Periarticular plate	ALTF, LTF	-	-
11	19.2	-	Delta	16	Narrow LCP	LTF	12	Autograft
12	17.5	Rush pin	Mono	49	Periarticular plate	ALTF	-	-
13	21.5	-	Delta	12	Periarticular plate	LTF	10	Autograft
14	18.5	-	Delta	35	Periarticular plate	ALTF	-	-
15	17.5	Plate	Delta	10	Periarticular plate	SPF	-	-

*Interval between the trauma and stage 1 treatment, †Interval between stage 1 and 2 treatments, ‡Interval between stage 2 and 3 treatments. EF=External fixator, LCP=Locking compression plate, ALTF=Anterolateral thigh flap, LTF=Local transposition flap, SF=Soleus flap, GF=Gastrocnemius flap, LAF=Local advancement flap, SPF=Sural perforator flap, DBM=Demineralized bone matrix, BT=Bone transport technique

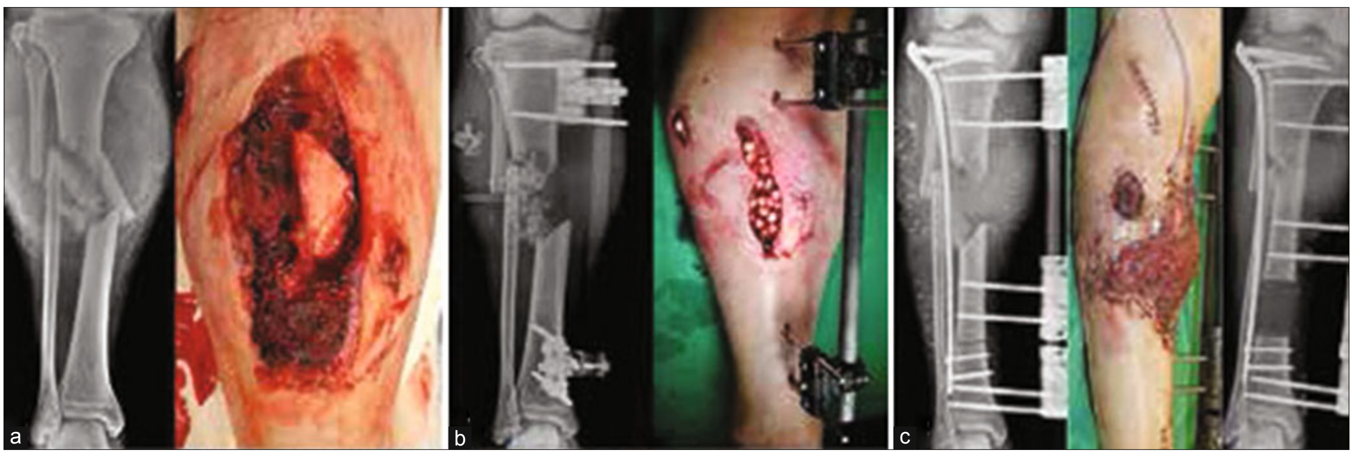

Figure 2: (a) X-ray anteroposterior view of leg bones with clinical photograph showing a right proximal tibia open fracture with severe bone defect (AO/OTA: 42-B3, Gustilo–Anderson: IIIb). (b) X-ray anteroposterior view of leg bones with clinical photograph showing that after wound irrigation and debridement, contaminated bone fragments were removed and antibiotics impregnated cement beads were inserted. A fracture was stabilized using a temporary ankle-spanning external fixator. (c) X-ray anteroposterior of leg bones, clinical photograph and x-ray anteroposterior view of leg bones showing that a anterolateral minimally invasive percutaneous osteosynthesis using locking compression plate proximal lateral tibial plate and bone transport procedure were performed at 2 weeks after initial treatment. Soft tissue coverage was performed using soleus flap and meshed skin graft. Docking of bone defect was achieved at 8 weeks after second surgery

radiological evidence of bone union with no pain at the fracture site.

Evaluations

To avoid potential bias, an independent observer, who was not part of the operative team, assessed all clinical and radiographic evaluations (C.H.P. and G.B.K.). The clinical evaluations were performed at the last followup using a simple and complete seven-scale scoring system for severe open fractures of the tibia according to Puno *et al.*[12] The seven factors were as follows: (1) Patient's freedom from pain (2) activities of daily living (3) range of motion (ROM) at the ankle and knee (4) residual deformity (5) radiographic examination for degenerative joint changes and malalignment (X-P change) (6) muscle strength of the foot using a five-point muscle grading system and (7) sensation as assessed through two-point discrimination, vibratory sensation and light touch. Full score in each category excluding of sensation category in this scoring system is 15 (full score in the sensation category is 10). A summation of the individuals gives a single comprehensive score for evaluation of overall function. A score of 90–100 represents an excellent result, 80–89 a good result, 70–79 a fair result and <70 a poor result. The ROM of the knee and ankle joints was measured using a goniometer and other parameters relevant to outcome status including gait, use of walking aids and return to previous employment were evaluated at the last followup. The New Injury Severity Score[13] and postoperative complications were also evaluated by chart review.

The radiographic evaluations were performed at regular intervals as 6 weeks, 3 months and monthly until radiographic healing occurred. Time to bone union was investigated and bone union was defined as when callus maturation was closed over 3/4 of the fracture faces on the anteroposterior and lateral radiographs and when no movement or tenderness was present at the fracture site. A tibial coronal and sagittal angulation and a shortening were measured at the last followup. An angular deformity was defined as an angulation of >5° according to the Milner's method.[14] A shortening was defined as a shortening of >10 mm in comparison with the unaffected side.

Results

Mean score of Puno scoring system was 87.4 (range 67–94) 9 patients were excellent, 5 patients were good, 1 case was fair and 1 patient was poor. Fourteen of the 15 patients (87%) showed satisfactory results. Mean ROM of the knee and ankle joints was 121.3° (range 90^0–130^0) and 37.7° (range 15^0–50^0), respectively. Four of the 15 patients (26.6%) had a limping gait and 3 patients (20%), who were more than 70 years old, used a cane at the last followup. Eight patients (53.3%) returned to previous employment and 7 patients changed jobs to less physically demanding work.

Bone union developed in all patients and mean time to union was 25 weeks (range 16–50 weeks). The mean coronal angulation was 2.1° (range 0°–4°) and sagittal was 2.7° (range 1°–4°). There was no angular deformity of more than 5°. Mean shortening was 4.1 mm (range 0–8 mm) and no shortening of more than 10 mm was observed.

Two patients who had severe soft tissue defect around ankle joint had limited motion of the ankle joint. One patient complained of skin irritation due to a protruding plate; the symptom was relieved after plate removal. Three patients underwent debridement and skin graft because of partial flap necrosis and 1 patient underwent revision surgery because of total flap necrosis. No patients developed superficial or deep wound infections.

Discussion

Severe open tibial fractures remain challenging injuries associated with a high risk of complications such as infection, nonunion and malunion for orthopedic surgeons.[2-4] Thus, suitable treatment protocol of severe open tibial fractures is controversial.[10,15-17]

In the present study, a two or three staged protocol was used in all fractures. It consists of immediate external fixation with NPWT and delayed soft tissue coverage with internal fixation using MIPO. An additional bone graft as a third staged procedure is performed early if lack of healing process is definitely observed in fractures with a severe metaphyseal bone defect. Staged procedure was used first in treatment of severe tibial plateau and pilon fractures, and several authors have reported good results.[18,19] A staged protocol also has been introduced as a treatment of open tibial fractures with good results.[9,10] However, reports of treatment using a staged protocol for open tibial fractures included mild to moderate open fractures such as grade II or IIIa.[9,10] To the best of our knowledge, this study is the first about the outcomes of treatment of staged management using the same protocol for Gustilo Anderson grade IIIb open tibial fractures.

Recently, "fix and flap" protocol has used as treatment of severe open tibial fractures.[6,15] This protocol is intended to shorten fracture healing time and lower infection rates as healthy soft tissues are brought early into fracture site, and it introduces important cellular and humoral elements to the healing process. However, the protocol has the risk of the failure of flap surgery due to unstable soft tissue condition. Moreover, it also has the potential risk of deep infection when open wound is contaminated severely. Severe open tibial fractures are sometimes accompanied by associated injuries because they are high energy injuries. In such cases, lengthy surgery as flap surgery can be difficult.

NPWT has been recently developed for the treatment of complex wounds. NPWT is associated with edema reduction, increased blood flow, and increased granulation tissue in the wound through continuous or intermittent employing negative pressure.[20,21] In this study, we performed internal fixation and soft tissue coverage after VAC was applied for about 2 weeks. This delayed soft tissue coverage with NPWT decreases the risk of deep infection and stabilizes the soft tissue condition. The main advantage of delayed soft tissue coverage with NPWT is that it decreases the risk of deep infection. Severe open fractures have a risk of deep infection that ranges from 16% to 44% despite many advances such as improved treatment protocols and new antibiotics in the care of open wounds.[22] Gopal *et al*.[15] reported a superficial infection rate of 21.2% (7/33) and a deep infection rate of 6.1% (2/33) in grade IIIb and IIIc open tibial fractures receiving treatment using "fix and flap" protocol. We thought that it is not a small risk of infection although superficial infection can be readily treated with antibiotics. Conroy *et al*.[23] reported that two deep infections (6.3%) occurred after immediate bony stabilization and early soft tissue cover in grade IIIb open tibial pilon fractures and amputation was performed in these cases due to failure of flap surgery. In this study, we never experienced a superficial or deep infection although this study has smaller sample size than previous reports. We thought that the low infection rate could be attributed to NPWT and delayed soft tissue coverage.

Another advantage of delayed soft tissue closure using NPWT is the decreased need for microsurgical procedures such as free flap surgery. Because NPWT leads to reduced size of the open wound, the open wound can be closed using a local flap instead of a free flap. Free flaps demand a long and costly procedure and a specialized team of plastic surgeons and are frequently associated with postoperative complications.[24] In the present study, 2 patients who would require free flap surgery at the initial trauma because of large size of the wound were treated instead using local flap such as gastrocnemius muscle transposition flap, fasciocutaneous transposition flap, and reverse sural artery flap after NPWT for 2–3 weeks.

Open tibial fractures sometimes result in severe bone defects due to contamination and loss of viability of bony fragments, particularly when associated with extensive skin and soft tissue damage. Therefore, in fractures with severe bone defect, early bone stimulating procedures may be necessary when lack of bone healing progression is obvious after definite fixation. Conventional autogenous bone graft is a good treatment option for bony defect and loss of bone healing progression.[25] However, in a large defect, vascularized fibular graft or bone transport procedure would be more useful than conventional bone graft [Figures 2 and 3]. In the present study, early bone

Figure 3: Anteroposterior lateral radiograph and clinical photo graph (at 14 months followup) showing a healed distal tibia without complication

stimulating procedures as stage 3 treatment were performed in 8 (53.3%) of 15 patients at mean 12.3 weeks after definite bony fixation and bone union was achieved in all patients. Therefore, we believe that early bone stimulating procedures should be considered when lack of bone healing progression is obvious for 10–12 weeks after definite fixation in fractures with a severe bone defect.

One of the limitations of this study is that the sample size was small. However, incidence of Gustilo Anderson grade IIIb open tibial fracture is low, and this study has more cases than previous studies.[16,26] Therefore, we believe that our results represent the results of treatment using staged protocol for Gustilo Anderson grade IIIb open tibial fractures. Another limitation of this study is that no alternative treatment or control group was included for comparison purposes and, thus, we suggest an additional study be undertaken to compare early and delayed soft tissue coverage with internal fixation in Gustilo Anderson grade IIIb open tibial fractures.

Conclusion

Staged treatment using NPWT decreased risks of infection and requirement of flap surgeries in Gustilo Anderson grade IIIb open tibial fractures. Early bone stimulating procedure should be considered when a severe bone defect is observed, or lack of bone healing progression is obvious after definite fixation. Therefore, staged treatment using NPWT could be a useful treatment option for Gustilo Anderson grade IIIb open tibial fractures.

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Conflicts of interest

There are no conflicts of interest.

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