

Research article

Open Access

## Negative pressure wound therapy for soft tissue injuries around the foot and ankle

Hyun-Joo Lee<sup>1</sup>, Joon-Woo Kim<sup>1</sup>, Chang-Wug Oh<sup>\*1</sup>, Woo-Kie Min<sup>1</sup>, Oog-Jin Shon<sup>2</sup>, Jong-Keon Oh<sup>3</sup>, Byung-Chul Park<sup>1</sup> and Joo-Chul Ihn<sup>1</sup>

Address: <sup>1</sup>Department of Orthopedic Surgery, Kyungpook National University Hospital, Daegu, Korea, <sup>2</sup>Department of Orthopedic Surgery, Yeungnam University Hospital, Daegu, Korea and <sup>3</sup>Department of Orthopedic Surgery, Korea University Guro Hospital, Seoul, Korea

Email: Hyun-Joo Lee - lidmania@hanmail.net; Joon-Woo Kim - orthopedics@naver.com; Chang-Wug Oh\* - cwoh@knu.ac.kr; Woo-Kie Min - wkmin@knu.ac.kr; Oog-Jin Shon - ossoj@med.yu.ac.kr; Jong-Keon Oh - jkoh@korea.ac.kr; Byung-Chul Park - bcpark@knu.ac.kr; Joo-Chul Ihn - jcihn@knu.ac.kr

\* Corresponding author

Published: 9 May 2009

Received: 25 August 2008

Accepted: 9 May 2009

*Journal of Orthopaedic Surgery and Research* 2009, **4**:14 doi:10.1186/1749-799X-4-14

This article is available from: <http://www.josr-online.com/content/4/1/14>

© 2009 Lee et al; licensee BioMed Central Ltd.

This is an Open Access article distributed under the terms of the Creative Commons Attribution License (<http://creativecommons.org/licenses/by/2.0>), which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited.

### Abstract

**Background:** This study was performed to evaluate the results of negative pressure wound therapy (NPWT) in patients with open wounds in the foot and ankle region.

**Materials and methods:** Using a NPWT device, 16 patients were prospectively treated for soft tissue injuries around the foot and ankle. Mean patient age was 32.8 years (range, 3–67 years). All patients had suffered an acute trauma, due to a traffic accident, a fall, or a crush injury, and all had wounds with underlying tendon or bone exposure. Necrotic tissues were debrided before applying NPWT. Dressings were changed every 3 or 4 days and treatment was continued for 18.4 days on average (range, 11–29 days).

**Results:** Exposed tendons and bone were successfully covered with healthy granulation tissue in all cases except one. The sizes of soft tissue defects reduced from 56.4 cm<sup>2</sup> to 42.9 cm<sup>2</sup> after NPWT (mean decrease of 24%). In 15 of the 16 cases, coverage with granulation tissue was achieved and followed by a skin graft. A free flap was needed to cover exposed bone and tendon in one case. No major complication occurred that was directly attributable to treatment. In terms of minor complications, two patients suffered scar contracture of grafted skin.

**Conclusion:** NPWT was found to facilitate the rapid formation of healthy granulation tissue on open wounds in the foot and ankle region, and thus, to shorten healing time and minimize secondary soft tissue defect coverage procedures.

### Introduction

Tendon and/or bone exposure commonly occurs in the foot and ankle region after acute trauma [1]. The conventional treatment method used for these uncovered, open wounds in the foot and ankle is skin grafting after the for-

mation of healthy granulation tissue by wet dressing [2]. However, the duration of treatment may be prolonged, and patients may experience severe pain during dressing changes [3]. Furthermore, it is difficult to form healthy granulation tissue by simple wet dressing, when a tendon,

bone, or implant is exposed. Accordingly, free flap surgery is often required, which requires substantial effort and introduces the issue of donor site morbidity [4].

Negative pressure wound therapy (NPWT) was first described by Argenta and Morykwas [2]. This technique can be used to cover exposed bone or soft tissue defects without frequent dressing changes, and reduces chronic edema and increases local blood supply, which enhances the formation of healthy granulation tissue. Several reports have been issued on the application of NPWT to soft tissue defects of the extremities, abdomen and chest [5,6]. However, reports regarding its use in the foot and ankle region are limited, though in this region tendon and bone exposures frequently occur after external injury or due to chronic ulcerative disease. The purpose of this study was to determine how NPWT helps healing and whether the technique can reduce the need for flap surgery for the treatment of acute or chronic open wounds in the foot and ankle region.

**Materials and methods**

Over the four year period from 2003 to 2006, 16 patients (12 males and 4 females) with soft tissue injuries in the foot and ankle region were treated with an NPWT device (V.A.C.,<sup>®</sup> Vacuum Assisted Closure, KCI, San Antonio, United States) at the authors' institute. All 16 patients were followed for more than 12 months (mean: 19 months, range: 13–39 months). Mean patient age was 32.8 (range: 3–67). All patients had experienced an acute

injury, caused by either a traffic accident in 12, a falling from a height in 2, and a crush injury in 2. Wound locations were on the medial side of the ankle in 3 cases, the lateral side of the ankle in 1 case, and of the dorsum of the foot in 12 cases. All patients had at least one tendon or bone exposed at the initiation of NPWT, and four had an associated infection (Table 1).

**Technique**

An NPWT device was applied after debriding necrotized tissues and cleansing contaminated wounds. When fractures were present, internal or external fixation was performed before application. The V.A.C.<sup>®</sup> system was used throughout. This consists of an evacuation tube, a collecting canister, a vacuum pump, and a multiporous polyurethane sponge, which directly contacts the wound. The sponge, which was designed to be 3–5 cm larger than wounds, was applied to defect sites and sealed with transparent cohesive film. The vacuum dressing was changed every 3–4 days and most procedures were performed at bedside. However, when necessary, debridement was performed in an operating room. A negative pressure vacuum pump was applied to wounds in continuous mode at a pressure of 100~125 mmHg. NPWT was stopped after confirming the formation of healthy granulation tissue. Skin grafting was performed when further coverage was required.

Wound types (acute or traumatic versus chronic) and location were noted, and durations, numbers, and fre-

**Table 1: Patient and wound details before and after negative pressure wound therapy**

No	Age	Sex	Injury	Site	Wound grade (before)	Wound grade (after)	Size (before)	Size (after)	Duration	Additional procedure	Complication
1	3	M	Ped TA	Dorsal	2	I	92	60	14	STSG	
2	7	M	Ped TA	Dorsal	3	I	23	9	17	STSG	scar contracture
3	7	M	Ped TA	Dorsal	2	I	60	42	16	STSG	scar contracture
4	10	M	Ped TA	Dorsal	3	I	36	16	13	STSG	
5	11	M	Sports injury	Lateral	4	I	27	20	23	STSG	
6	18	F	In car TA	Dorsal	2	I	70	50	19	STSG	
7	22	M	In car TA	Dorsal	3	I	94.5	87	17	STSG	
8	26	M	F/D	Medial	2	I	9	4	12	STSG	
9	27	M	In car TA	Dorsal	3	I	103	85	15	STSG	
10	44	M	Crushing	Dorsal	3	I	52	35	17	STSG	
11	47	F	Ped TA	Dorsal	2	I	151	91	27	STSG	
12	53	M	F/D	Medial	2	I	14	8	11	STSG	
13	54	F	Crushing	Medial	3	I	72.5	17	12	STSG	
14	63	F	Motorcycle TA	Dorsal	3	I	12	8	18	FTSG	
15	66	M	In car TA	Dorsal	3	3	45	39	21	free flap	
16	67	M	Ped TA	Dorsal	3	I	104	81	29	STSG	
<b>Mean</b>	<b>32</b>				<b>2.69</b>	<b>1.13</b>	<b>56.4(cm<sup>2</sup>)</b>	<b>42.9(cm<sup>2</sup>)</b>	<b>18.4</b>		
	<b>(years-old)</b>								<b>(days)</b>		

TA: traffic accident, Ped(pedestrian), F/D: fall down, STSG(split thickness skin graft), FTSG(full thickness skin graft)

**Table 2: Details of the open wound scoring system used**

Score (grade)	Status of wound
0	Closed wound
1	Skin or soft tissue defect
2	Bone, tendon, implant exposure(any 1)
3	Bone, tendon, implant exposure(any combination of 2 or more)
4	Associated or Residual infection

quencies of V.A.C. system applications were recorded. Before and after NPWT treatment, sizes of soft tissue defects were assessed using squared paper. Wounds were categorized into 5 groups based on degree of exposure and the presence of concomitant infection, which was graded from 0 to 4 (Table 2). Final coverage techniques, including primary closure, split thickness skin grafting, and pedicled local and vascularized free flap grafting were documented. Furthermore, any complications attributable to NPWT treatment were noted.

**Results**

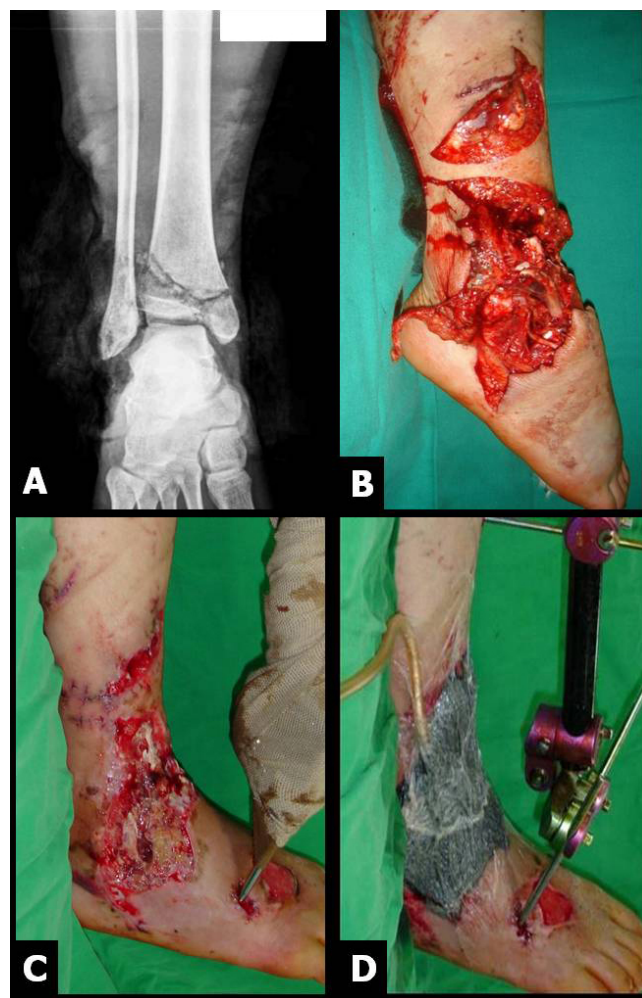
The mean duration of therapy was 18.4 days (range, 11–29 days), and dressings were changed 4.5 times on average. Mean wound size at treatment initiation was 56.4 cm<sup>2</sup> (9–151 cm<sup>2</sup>), and this reduced to 42.9 cm<sup>2</sup> (4–81 cm<sup>2</sup>) at treatment completion, an average wound area reduction of 24%. Fifteen of the 16 patients achieved an improved wound status, and in these exposed tendons or bone was covered with healthy granulation tissue (Figures 1, 2). After NPWT, skin grafting was performed to cover granulation tissue in 15 cases (a split-thickness skin graft in 14 cases and a full-thickness skin graft in 1 case). One patient experienced treatment failure, and required a free flap to cover exposed bone and tendon. The average wound grade was 2.69 at the start of treatment, and 1.13 at the end of treatment.

No complication occurred that could be directly attributed to NPWT, such as, a deep infection or bleeding. In terms of minor complications, four patients experienced itchiness of skin in the region of NPWT application. In addition, 2 patients experienced scar contractures in grafted areas, which were rescued using a releasing procedure.

**Discussion**

Traumatic injuries around the foot and ankle are often associated with significant skin loss, which results in the exposure of tendons, bone, or hardware, and associated wound-management difficulties. These injuries are similar in many ways, to chronic ulcerative lesions of the foot associated with ischemic diseases, such as, diabetes mellitus. The rapid formation of granulation tissue and blood vessels are essential for the healing of these wounds. Tra-

ditionally, frequent wet dressing changes (3–4 times/day) are used to treat such cases, but this treatment is protracted and painful [3,7]. Furthermore, interstitial fluid from open wounds reduces local blood supply and disturbs wound healing due to its collagenase and metalloproteinase constituents [8,9]. From this viewpoint, NPWT is highly effective at clearing interstitial fluid, and in the



**Figure 1**  
**A severe open fracture around the ankle in a 20 year-old woman (A & B). After the debridement of necrotized tissue (C), NPWT was applied (D).**



**Figure 2**  
**At 22 days of NPWT, sufficient granulation covered tendons (E) to perform skin graft. At 1 year postoperatively, the wound had healed well (F & G).**

majority of our patients, wounds were covered with healthy granulation tissue after 4.5 sponge changes, without additional flap surgery. DeFranzios<sup>5</sup> also reported that NPWT enhances rapid granulation formation in over 80% of patients as compared with a simple wet dressing. Furthermore, it has been well reported that NPWT provides a continuous physical stimulus that enhances the formation of new vessels and granulation tissues [10,11].

Soft tissue defects in the foot and ankle region usually require local or free flap surgery when a skin graft procedure is not applicable due to limited granulation tissue formation<sup>1</sup>. A split-thickness skin graft is not recommended for wounds with exposed bone or neurovascular structures, or for wounds involving the weight-bearing surface of the foot [12]. In a comparative study of traditional dressings and NPWT for lawnmower injuries of the lower leg [13], the need for free flap surgery was found to be decreased by 30%. A remarkable reduction in the requirement for secondary soft tissue operation is believed to be a big advantage of NPWT [14]. Dedmond [15] also reported that wounds of grade 3 with an accompanying open tibial fracture healed without the need for a secondary soft tissue operation, such as, a free flap. In the present study, the severities of open wounds were noticeably reduced after NPWT; only one patient needed a free flap to cover exposed bone and tendon.

The prevention of deep infection is essential during the treatment of soft tissue defects, and simple wet dressing may be inadequate in this context, because wounds are inevitably exposed to the atmosphere. On the other hand, NPWT not only seals open wounds but evacuates hematomas, exudates, and possible pathogens by the application of negative pressure [10,16,17]. Furthermore, it has been reported that NPWT is effective at treating deep infections [18]. In the present study, no case of infection during the

treatment period occurred. Accordingly, we consider that NPWT probably also reduces soft tissue defect infection rates.

Some technical difficulties have been reported when NPWT was used to treat foot wounds [19], but we did not encounter these problems. In terms of complications, we did encounter 2 cases of skin graft scar contractures, which can reduce foot function. Successful scar release was achieved in these two cases. But, in certain cases, flap surgery may be considered to prevent scar contractures [20], instead of NPWT.

This study has several limitations that require consideration, namely, that the size of data is small, and there was no control group, which reduced objectivity. We suggest that a prospective randomized multicenter trial be undertaken to determine the merits of NPWT for the treatment of soft tissue defects of the ankle and foot. However, based on the results of previous studies on its use for the treatment of other injuries at other locations, it appears that NPWT plays a significant role in the formation of granulation tissue and in the prevention of infection [21].

Our results add to growing evidence that NPWT is a useful adjunctive treatment for open wounds around the foot and ankle. In the present study, it was found to facilitate the rapid formation of granulation tissue, to shorten healing time, and to reduce remarkably the need for additional soft tissue reconstructive surgery.

### Competing interests

The authors declare that they have no competing interests.

### Authors' contributions

CWO, HJL carried out concept design, patient recruitment and follow-up, data collection and analysis, and manuscript writing. JWK carried out literature search and data analysis. WKM carried out data collection, patient follow up, data analysis and manuscript writing. OJS, JKO, BCP, JCI conceived of the study, and participated in its design and coordination. All authors read and approved the final manuscript for publication.

### Acknowledgements

The authors thank Hwa-Ryun, Sarah, Park (Archmere Academy, Senior Wilmington, Delaware, United States) for her editorial assistance with the manuscript. This work was supported by BK 21. This study was conducted at Kyungpook National University Hospital, Daegu, Korea

### References

1. Mendonca DA, Cosker T, Makwana NK: **Vacuum-assisted closure to aid wound healing in foot and ankle surgery.** *Foot Ankle Int* 2005, **26**:761-766.
2. Argenta LC, Morykwas MJ: **Vacuum-assisted closure: a new method for wound control and treatment: clinical experience.** *Ann Plast Surg* 1997, **38**:563-576.

3. McCallon SK, Knight CA, Valiulus JP, Cunningham MW, McCulloch JM, Farinas LP: **Vacuum-assisted closure versus saline-moistened gauze in the healing of postoperative diabetic foot wounds.** *Ostomy Wound Manage* 2000, **46**:28-32.
4. DeFranzo AJ, Argenta LC, Marks MW, Molnar JA, David LR, Webb LX, Ward WG, Teasdall RG: **The use of vacuum-assisted closure therapy for the treatment of lower-extremity wounds with exposed bone.** *Plast Reconstr Surg* 2001, **108**:1184-1191.
5. DeFranzo AJ, Marks MW, Argenta LC, Genecov DG: **Vacuum assisted closure for the treatment of degloving injuries.** *Plast Reconstr Surg* 1999, **104**:2145-2148.
6. Webb LX: **New techniques in wound management: vacuum assisted wound closure.** *J Am Acad Orthop Surg* 2002, **10**:303-311.
7. Lionelli GT, Lawrence WT: **Wound dressings.** *Surg Clin North Am* 2003, **83**:617-638.
8. Bucalo B, Eaglstein WH, Falanga V: **Inhibition of cell proliferation by chronic wound fluid.** *Wound Repair Regen* 1993, **1**:181-186.
9. Wysocki AB, Staiano-Coico L, Grinnell F: **Wound fluid from chronic leg ulcers contains elevated levels of metalloproteinases MMP-2 and MMP-9.** *J Invest Dermatol* 1993, **101**:64-68.
10. Morykwas MJ, Argenta LC, Shelton-Brown EI, McGuirt W: **Vacuum-assisted closure: a new method for wound control and treatment: animal studies and basic foundation.** *Ann Plast Surg* 1997, **38**:553-562.
11. Yuan-Innes MJ, Temple CL, Lacey MS: **Vacuum-assisted wound closure: A new approach to spinal wounds with exposed hardware.** *Spine* 2001, **26**:E30-33.
12. Alonso JE, Sanchez FL: **Lawn-mower injuries in children: a preventable impairment.** *J Pediatr Orthop* 1995, **15**:83-89.
13. Shilt JS, Yoder JS, Manuck TA, Jacks L, Rushing J, Smith BP: **Role of vacuum-assisted closure in the treatment of pediatric lawn-mower injuries.** *J Pediatr Orthop* 2004, **24**:482-487.
14. Mooney JF 3rd, Argenta LC, Marks MW, Morykwas MJ, DeFranzo AJ: **Treatment of soft tissue defects in pediatric patients using the V.A.C. system.** *Clin Orthop* 2000, **376**:26-31.
15. Dedmond BT, Kortesis B, Pungner K, Simpson J, Argenta J, Kulp B, Morykwas M, Webb LX: **Subatmospheric pressure dressings in the temporary treatment of soft tissue injuries associated with type III open tibial shaft fractures in children.** *J Pediatr Orthop* 2006, **26**:728-732.
16. Stannard JP, Robinson JT, Anderson ER, McGwin G Jr, Volgas DA, Alonso JE: **Negative pressure wound therapy to treat hematomas and surgical incisions following high-energy trauma.** *J Trauma* 2006, **60**:1301-1306.
17. Wongwarawat MD, Schnall SB, Holtom PD, Moon C, Schiller F: **Negative pressure dressings as an alternative technique for the treatment of infected wounds.** *Clin Orthop* 2003, **414**:45-48.
18. Canavese F, Gupta S, Krajbich JI, Emara KM: **Vacuum-assisted closure for deep infection after spinal instrumentation for scoliosis.** *J Bone Joint Surg Br* 2008, **90**:377-381.
19. Clare MP, Fitzgibbons TC, McMullen ST, Stice RC, Hayes DF, Henkel L: **Experience with the vacuum assisted closure negative pressure technique in the treatment of non-healing diabetic and dysvascular wounds.** *Foot Ankle Int* 2002, **23**:896-901.
20. Attinger CE, Ducic I, Cooper P, Zelen CM: **The role of intrinsic muscle flaps of the foot for bone coverage in foot and ankle defects in diabetic and nondiabetic patients.** *Plast Reconstr Surg* 2002, **110**:1047-1054.
21. Herscovici D Jr, Sanders RW, Scaduto JM, Infante A, DiPasquale T: **Vacuum-assisted wound closure (VAC therapy) for the management of patients with high-energy soft tissue injuries.** *J Orthop Trauma* 2003, **17**:683-88.

Publish with **BioMed Central** and every scientist can read your work free of charge

"BioMed Central will be the most significant development for disseminating the results of biomedical research in our lifetime."

Sir Paul Nurse, Cancer Research UK

Your research papers will be:

- available free of charge to the entire biomedical community
- peer reviewed and published immediately upon acceptance
- cited in PubMed and archived on PubMed Central
- yours — you keep the copyright

Submit your manuscript here:  
[http://www.biomedcentral.com/info/publishing\\_adv.asp](http://www.biomedcentral.com/info/publishing_adv.asp)

