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The Different Negative Pressure Wound Therapy Effects on Flap Edge Survival

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Abstract

Negative Pressure Wound Therapy (NPWT) effectively manages complex wounds by promoting fluid drainage, stabilizing the wound environment, and reducing bacterial load. It aids in granulation tissue formation and modulation of inflammatory reactions. NPWT is increasingly used in reconstructive surgery, particularly in flap procedures, enhancing wound healing and cosmetic outcomes while reducing flap complications. Despite concerns about flap compromise, clinical trials demonstrate low flap loss rates with NPWT. Strategies like observation windows and implantable Doppler devices help overcome monitoring challenges. However, conclusive evidence regarding NPWT's safety and impact on flap vascularity is limited due to scarce studies.

The study involved 40 healthy adult patients, mostly male, with soft tissue defects primarily caused by road traffic accidents. They were split into two groups: NPWT (25 patients) and conventional dressing (15 patients). The NPWT group was further categorized into high pressure (8 patients) and low pressure (17 patients) subgroups. Results showed lower flap edema in NPWT groups compared to controls, but high pressure NPWT led to higher flap ischemia and infection rates at the flap edge. Overall, low pressure NPWT yielded the best clinical and aesthetic outcomes with fewer complications. The study suggests a delayed NPWT approach and low-pressure settings for optimal vascular perfusion in Fasciocutaneous flaps, emphasizing the need for further trials to establish its efficacy and determine ideal pressure settings for different flap types.

Keywords

NPWT- Negative Pressure wound Therapy
VAC- Vacuum Assisted Closure
STSG- Split Thickness Skin Graft

Introduction

There are many challenges encountered in the reconstruction of large soft tissue defects after trauma or surgery, mainly wound contamination, inadequate coverage and reconstructive flaps compromise. **(Yu et al., 2009)**

Negative pressure wound therapy (NPWT), introduced in the last decade, aids wound healing through mechanisms involving both mechanical and biological responses. It reduces wound size, exudate accumulation, and edema through macrostrain, while microstrain promotes cellular proliferation and angiogenesis.**(Daigle et al., 2013)**

Recent studies suggest NPWT may enhance flap vasculature, hasten healing, and reduce complications like pain and infection. However, its precise impact on flap survival and vascular patency remains unclear, necessitating further evaluation of pressure levels and application methods for reliable use at the flap edge. **(Opoku-Agyeman et al.,2019**)

Literature review

In the fields of wound management and reconstructive surgery, the use of NPWT for wound treatment has maintained a steady role. Its usage following free flap and pedicled flap procedures have been added to its extended list of indications. NPWT is employed in free flap surgery for a variety of purposes, mainly for promoting wound healing and managing flap complications.**(Yu et al., 2017)**

Muscle flaps frequently require revision or debulking treatments because of their bulky appearance and low level of aesthetic outcome. Significantly less edema has been observed after application of the NPWT, which subsequently improves tissue perfusion & drainage compared to the standard dressing. **(Chim et al., 2022)**

NPWT could be used safely on fascio-cutaneous flaps, in a clinical trial in 2017, a total of 35 ALT free flaps were managed with NPWT, the purpose of applying NPWT to these flaps was to improve flap edema, enhance the formation of granulation tissue and clear the wound bed of exudate and infectious debris. **(Bi, 2017)**

Despite these advantages, NPWT has been rarely utilized in the context of microsurgical reconstructive surgeries, that may be due to the concerning issues regarding its application on flaps. One major issue is that the flap may get compressed by the negative pressure applied by the device, leading to flap compromise and flap necrosis. However, subsequent clinical trials have demonstrated a free flap loss rate of less than 5% following the use of NPWT, which is within the generally reported range of free flap loss. **(Bui et al., 2007)**

Another issue about the use of NPWT on flaps is the masking of clinical monitoring of the free flap. Nevertheless, many tricks have been advocated to overcome this obstacle. One strategy is to create small openings in the applied foam dressing as observation window of the flap and facilitated the examine the arterial flow by a handheld Doppler. Another strategy is to use implantable Doppler devices that have a slightly higher sensitivity in free flap vascularity monitoring more than subjective monitoring. These devices have achieved high flap salvage rate in many clinical trials for free flap monitoring. **(Lenz et al., 2017)**

The degree of negative pressure, its mode (continuous Vs intermittent), duration of NPWT use and dressing change interval varied among clinical trials. The intermittent mode of NPWT was found to be more effective than continuous mode. **(Mouës et al., 2011)**

Pressure should be adjusted based on the type of wound, architecture of surrounding tissue and tolerance of the patients. In order to establish an adequate flap security with tissue angiogenesis, average one week of negative pressure therapy is advised. **(Malsiner et al., 2015)**

The safety and effect of NPWT application on flap vascularity remain nonconclusive due to limited studies in literature and most studies are retrospective in nature with low evidence.**(Marouf et al., 2022)**

Patients and Methods

The study was designed as a prospective comparative clinical study at Plastic Surgery Department, Aswan University hospitals at period of one year starting from May 2022 to June 2023. The study included adult patients between (16-50 years) with post-traumatic or post-tumor excision soft tissue defects, reconstructed by fasciocutaneous flaps, and excluded Patients with associated severe regional injuries, uncontrolled comorbidities, established flap compromise, or revision cases.

The study included 40 patients, and they were randomly allocated into three groups:

Group (A): High negative pressure intermittent mode was applied at the flap edge.

Group (B): Low negative pressure intermittent mode was applied at the flap edge.

Group (C): Conventional dressing (cotton gauze) was applied over flaps (control group).

In Group (A), the VAC machine system *(Smith and Nephew's system)* was set to negative pressure ranging between 80 and 120 mmHg according to each case, on intermittent mode (5 minutes active and 2 minutes off). While in group (B), it was set to negative pressure ranging between 20 and 60 mmHg on intermittent mode. The application of NPWT was done at the distal

edge of the flap after congestion was observed in the cases. The wound dressing was changed asneeded in every case.**Figure 1**

Figure 1Smith and Nephew's VAC machine system.

The following parameters were recorded:

(1) The timing and change frequency of dressing application.

(2) The flap edge vascular progress and wound healing rate.

(3) The degree of edema and other possible complications.

Results

The study included 40 patients that were divided into three groups. Male gender for all groups was about (75%) and female gender was about (25%) with the average mean age of 30 years old (Sum SD±12). Out of the included 40 patients, there were 4 diabetic patients, and 7 patients were smokers (more than 5 cigarettes / day). **Table 1**

Table 1Demography, medical diseases & etiologic causes of soft tissue defects in study groups.

	Group A (n=8)		**Group B(n=17)**		**Group C(n=15)**		**P-Value**
Age (years) (Mean± S.D)	32.1 ± 12.4		30.4 ± 11.9		28.8 ± 11.6		(0.454)
Sex	**N**	**%**	**N**	**%**	**N**	**%**	
Males	6	75%	12	70%	12	80%	(0.36)
Females	2	25%	5	30%	3	20%	
BMI (Mean± S.D.)	22.3 ± 2.97		21.8 ± 2.77		22.8 ± 2.36		(0.25)
Diabetes mellitus	1	12.5 %	22	11.7 %	11	6.7 %	(1.0)
Smoking	2	25 %	22	11.7 %	33	20 %	(1.0)
Etiology of the defect							
Trauma	6	75%	15	88.2%	12	80%	
Electric Burn	1	12.5 %	1	5.9%	2	13.3%	
Pressure ulcer	1	12.5%	1	5.9%	1	6.7%	

All cases had skin & soft tissue defects due to trauma predominantly (78%), post electric burn (17%) or pressure ulcer (5%)**Figure 2**.Some cases required coverage of the donor site of the flap with STSG to ensure tension-free closure.

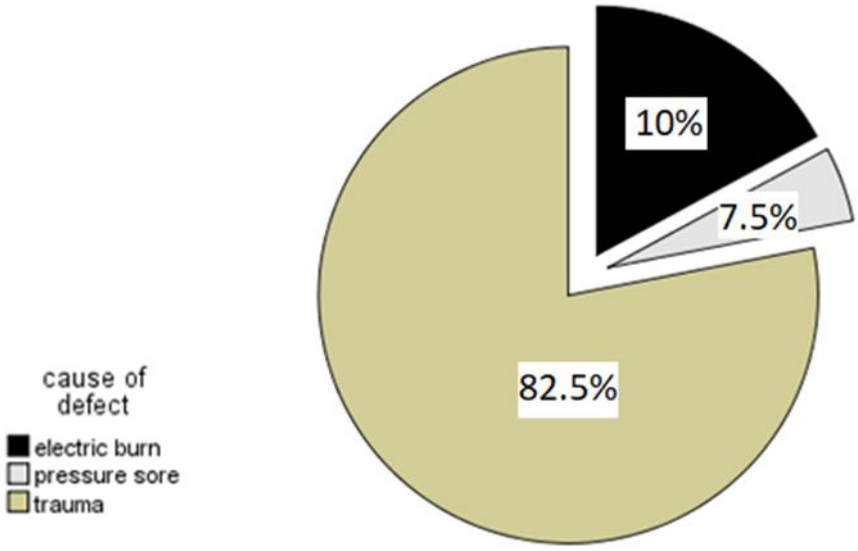

Figure 2Pie chart represents the percentage of causes of soft tissue defects in the study groups.

Postoperative assessment of the flaps included daily evaluations of vascularity, edema, and complications such as congestion, ischemia, infection, and wound dehiscence. This continued until wound stabilization around the 1st- 2ndweek post-surgery. Dressings were changed every 2-3 days, and patients were regularly monitored in outpatient clinics until complete skin healing was confirmed or further interventions like skin grafts or flap revisions were considered.

The study found that complete healing was defined by full wound epithelization without the need for additional wound coverage. Participants in the low-pressure group achieved primary healing successfully and more quickly, with an average of 9.4 days. In contrast, some patients in high pressure and control groups did not achieve primary healing, with percentages of 12% and 18%, respectively. These groups required longer times for complete healing, averaging 21 days and 24 days, respectively, often necessitating secondary healing or interventions such as flap revision or skin grafting to cover remaining raw areas.**Table 2**

Table 2The percentage of patients achieved primary healing & average healing time among study groups.

Groups	**Primary Healing**		**Healing Time (days)**	
	frequency	**percentage**	**Mean**	**SD**
A(n=8)	7	87.5 %	20.88	4.324
B(n=17)	17	100 %	9.41	3.318
C(n=15)	13	81.3 %	24.19	3.250

The study found that NPWT groups (A) and (B) showed significantly lower levels of edema compared to group (C), which used conventional dressing. In the low pressure NPWT group, edema was mild in 87% of patients and moderate in 13%. Similarly, in the high pressure NPWT

group, edema was mild in 88% and moderate in 12%. No severe edema was observed in either NPWT group. In contrast, the conventional dressing group had higher incidences of edema, with 18% experiencing severe edema, 44% moderate edema, and 38% mild edema.**Figure 3**

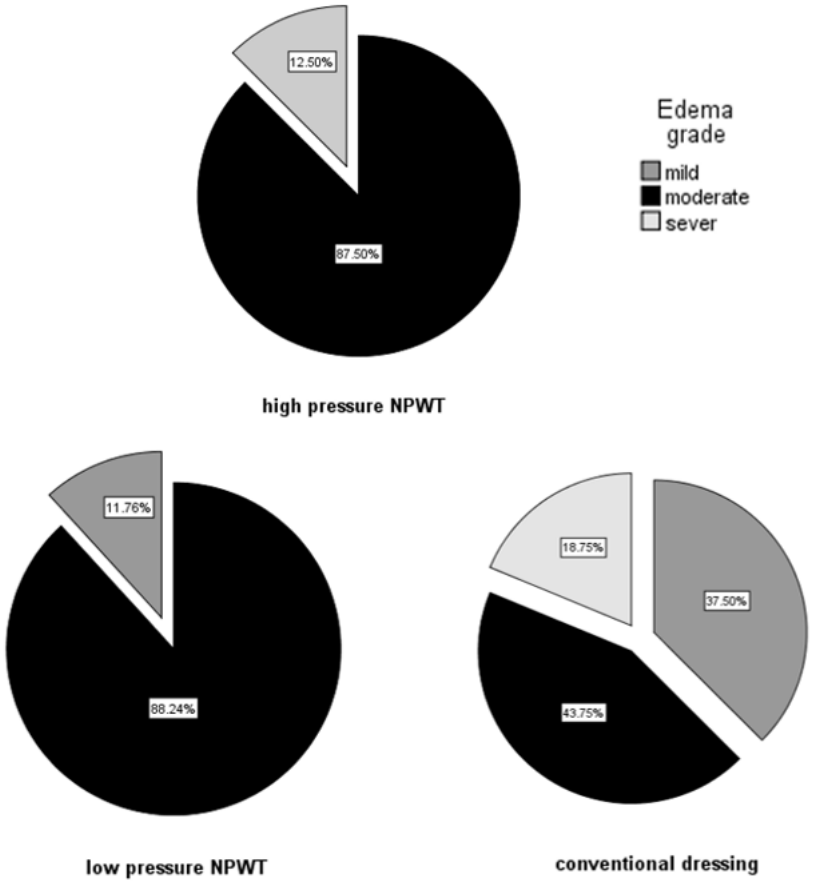

Figure 3Degree & percentage of flap edema among study groups.

Regarding flap complications, flap ischemia primarily occurred in cases using high pressure VAC dressing, affecting the flap edge where the foam was applied. This ischemia typically emerged within 2-3 days after application, without preceding congestion or compromise of the flap pedicle. In contrast, only one case experienced flap edge ischemia with low pressure VAC dressing (-60mmHg NPWT over a rotational scalp flap). The conventional dressing group saw ischemia in four cases, resulting in total flap loss in two cases due to irreparable damage to the flap pedicle. The difference in ischemia rates between groups was statistically significant.**Figure 4**

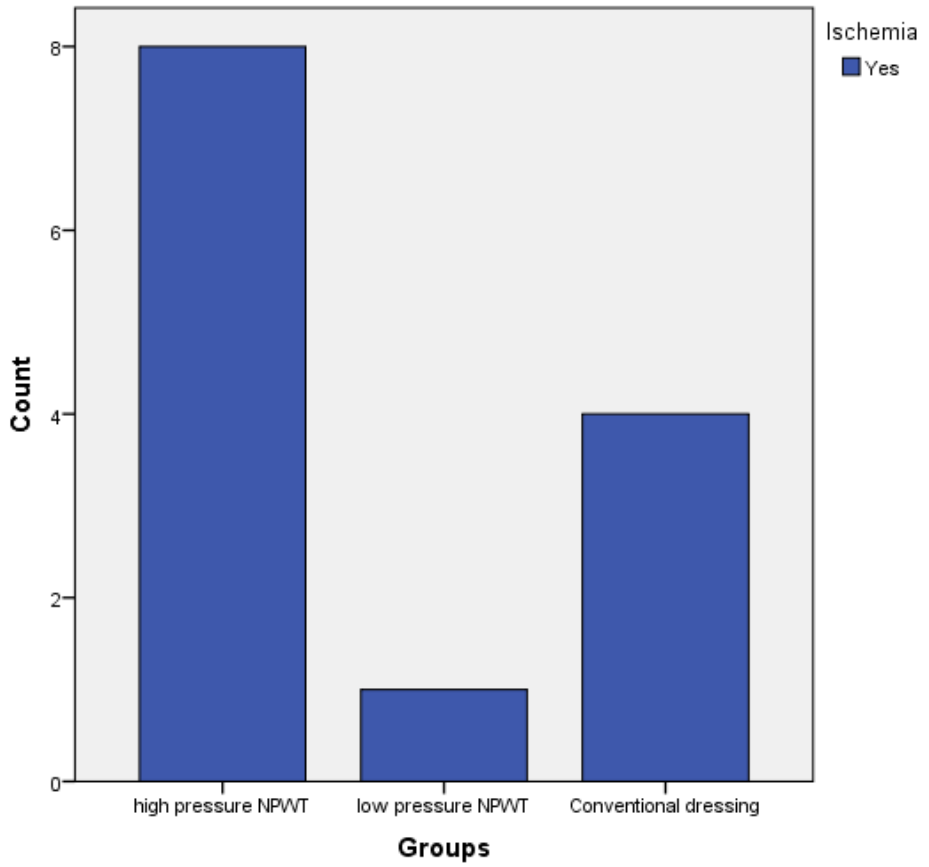

Figure 4 Bar chart showing incidence of flap ischemia among study groups.

Moreover, infection occurred more frequently in conventional dressing groups than the NPWT groups. Also, it was noticed that the low-pressure group had lower incidence of infection than the high-pressure group. **Table 3**

Table 3 Flap infection incidence within the study groups.

Groups	**Infection**		**X^2**	**P-value**
	Frequency	**Percentage**		
A (n=8)	2	25%	5.832	0.054
B (n=17)	3	17.6%		
C (n=15)	5	33.3%		

Case Presentation

Case (1):

A 16-year-old male patient with post traumatic soft tissue defect over ankle & dorsum of Lt. foot. Reconstruction was done with pedicled reversed sural flap.**Figure 5**

Figure 5P.T soft tissue defect over dorsal aspect of lt. foot & ankle

In the 2nd post operative day, there was moderate flap edema & congestion. NPWT was applied at distal edge of the flap on -40 mmHg intermittent mode. After 5 days of NPWT, the flap edema and congestion markedly resolved. Then, complete flap healing was achieved after 10 days.**Error! Reference source not found.**

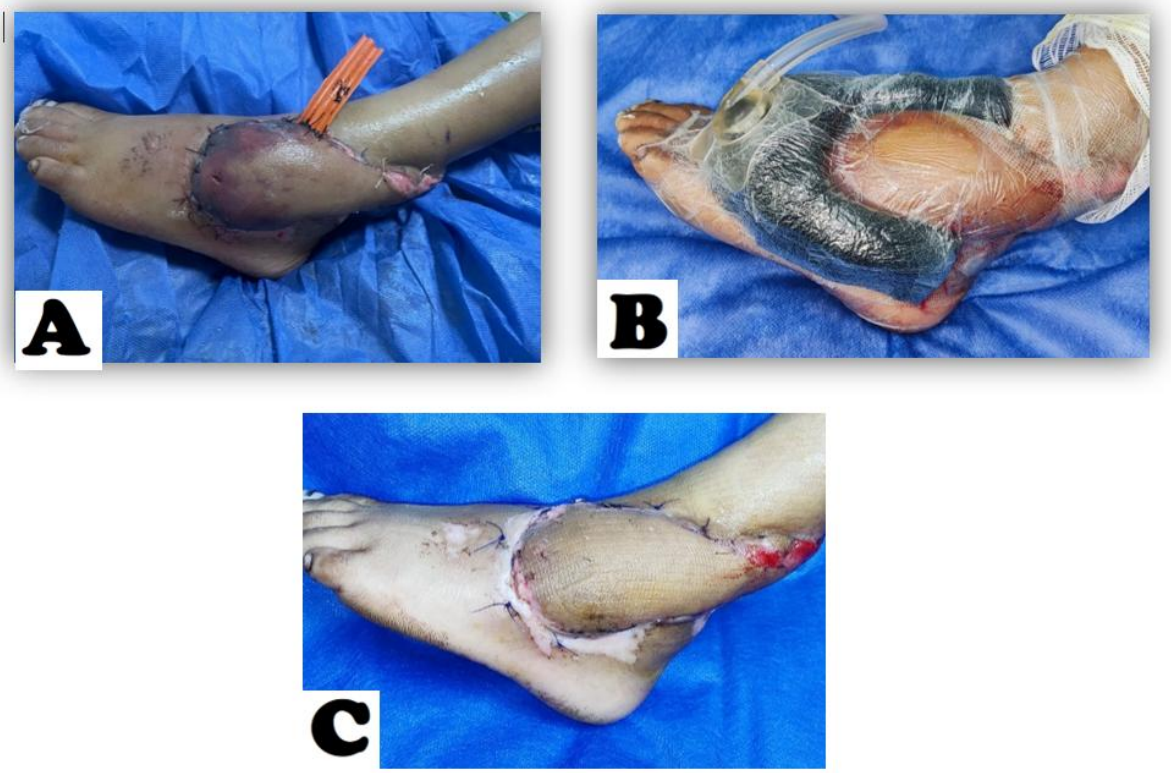

Figure 6Flap congesion & edema at the 3rd post operative day (A), Post operative day 7. Resolution of sural flap edema & congestion after 5 days of NPWT application (B)&(C)

Case (2):

A18-year-old male patient had Rt. ischial pressure sore grade IV, that was reconstructed with pedicled anterolateral thigh (ALT) flap**Figure** .

Figure 7 Preoperative photo of Rt.Ischeal pressure sore, reconstructin was done with ALT flap

After 3 days, there was moderate congestion at the flap distal part. NPWT was applied at distal edge of the flap on -120 mmHg intermittent mode.**Figure**

Figure 8 Flap congestion at the distal edge (after 3 days) & the application of NPWT

After 2 days of negative pressure skin congestion was noticed to progress to superficial ischemia.NPWT magnitude was tailored to -80 mmHg and re-applied for another 3 days. However, the flap ischemiaat the distal part progressed to full thickness ischemia**Figure** .The NPWT was discontinued, and the patient had surgical debridement for the necrotic tissue. Then the defect was covered with STSG. Complete healing was achieved after 3 weeks.

Figure 9 Distal flap ischemia occurred at the site VAC dressing application at the flap edge

Discussion

The negative pressure wound therapy started to have an established role in the management of different varieties of complex wounds. It appeared to optimize the healing process environment by increasing tissue perfusion, granulation tissue formation and removing tissue debris and fluid exudate and reducing edema formation which would reduce the tissue bioburden and decrease the bacterial load at the wound site **(Morykwas et al., 2006)**.

The immediate application as a wound care modality for patients undergoing reconstructive surgery with flap transfer, or as a salvage technique for compromised flaps are still under investigation. There are relatively few clinical trials trying to delineate its role**(Marouf et al., 2022).**

This study assessed the effectiveness and safety of Negative Pressure Wound Therapy (NPWT) for fasciocutaneous flaps in 40 healthy adults, mostly males, due to higher outdoor trauma exposure. It found that NPWT, applied at pressures of -60 to -120 mmHg, was safe and resulted in fewer flap failures compared to traditional dressing methods. Concerns about NPWT included the risk of flap pedicle compression and challenges in monitoring free flaps without removing the dressing. Solutions such as small observation windows and implantable Doppler devices have been developed for better flap monitoring, though these come with higher costs and complexity**(Lin et al., 2018).**

There is debate over whether to use Negative Pressure Wound Therapy (NPWT) on flaps immediately from the first day to prevent complications or to wait until complications like flap edema and congestion appear. Some studies suggest delaying NPWT until stable flap perfusion is established, while other research proposes that early application of NPWT can enhance skin circulation and improve flap perfusion as the case in the present study**(Chim et al., 2022).**

Negative Pressure Wound Therapy (NPWT) has been shown to reduce flap edema and thickness, improving aesthetic outcomes. In this study, moderate and severe edema was more common in control groups, while mild edema was predominant in NPWT groups. This aligns with other research indicating that NPWT significantly decreases edema and bulk, particularly in muscle flaps, thereby enhancing the appearance of reconstructive flaps and potentially reducing the need for revision or debulking.

In the study, high negative pressure NPWT (between -80 to -120 mmHg) caused flap edge ischemia in all cases, leading to the decision to limit further enrollment in this group. In contrast, the low-pressure NPWT group (between -20 to -60 mmHg) had a lower incidence of flap edge ischemia, occurring in only one case. High pressure likely compressed the superficial vascular plexus, causing ischemia, while low pressure, especially with intermittent mode, reduced this compression and improved outcomes.

Previous studies have shown that the impact of negative pressure wound therapy (NPWT) on blood perfusion varies with distance from the skin surface: hyper perfusion occurs at 2.5 cm, hypoperfusion at 0.5 cm, and no effect deeper than 5 cm. NPWT can help relieve congestion and edema by draining stagnant venous blood, but it may also cause arterial ischemia in small arterioles. This explains why high-pressure NPWT groups in our study had higher rates of ischemia and wound dehiscence at flap edges. The dermal and subdermal plexuses in superficial flaps are particularly vulnerable to high negative pressures. Recent studies also report increased ischemia and infection rates with high-pressure NPWT, highlighting the need for careful use to prevent vascular compromise**(Chen et al., 2021)**.

In the study, the infection rate was highest in the conventional dressing group (33%), compared to 25% in the high-pressure NPWT group and 17% in the low-pressure NPWT group. It is believed that infections often developed alongside ischemia. This is consistent with previous research, which suggests that infections may arise from contamination during the VAC dressing application or from inadequate sealing by the transparent vacuum sealer used over the foam**(Ernest et al., 2017)**.

NPWT improved healing and reduced the time to complete recovery for fasciocutaneous flaps. In the low-pressure NPWT group, all cases achieved primary healing within an average of 10 days without additional interventions. In contrast, 12% of high-pressure NPWT cases and 19% of control group cases did not achieve primary healing, often due to complications like flap ischemia and infection. These cases required secondary interventions, such as surgical debridement, flap revision, or coverage with skin grafts, extending healing times to 21 days for the high-pressure group and 24 days for the control group.

Nevertheless, more clinical trials are needed in the future to validate the true effects of the NPWT on flap vascularity and salvage.

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