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COMPARATIVE EVALUATION OF MACHINE-BASED AND WALL-MOUNTED VACUUM-ASSISTED CLOSURE SYSTEMS IN THE MANAGEMENT OF CHRONIC NON-HEALING ULCERS

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ABSTRACT

Background: Chronic non-healing ulcers remain a significant burden, especially in diabetic patients, often leading to infection, prolonged morbidity, and risk of amputation. Negative Pressure Wound Therapy (VAC) has emerged as an effective treatment, with machine-based systems well established and wall-mounted systems widely used in resource-limited settings. This study compared the effectiveness of both modalities across varying wound sizes.

Materials and Methods: A prospective observational study was conducted on 180 patients with chronic ulcers (>3 months) at Kempegowda Institute of Medical Sciences and Research Centre (KIMS), Bengaluru. Patients were grouped by wound size: Group A (≤50 cm², n=58), Group B (51–100 cm², n=60), and Group C (>100 cm², n=62). All underwent wound debridment followed by two cycles of VAC therapy (5 days each). Wall-mounted VAC applied continuous suction (-125 mmHg), while machine-based VAC delivered intermittent suction (-80 to -150 mmHg). Outcomes assessed included wound size reduction, contraction rate, and granulation tissue formation (Wagner grading).

Results: VAC therapy resulted in significant wound size reduction in all groups, with the greatest contraction in Group C (8.15 ± 4.62 cm² and 4.94 ± 4.54 cm² per cycle, p<0.001). Group B showed moderate contraction, while Group A had minimal reduction. More than 95% of patients achieved Wagner Grade 4 granulation tissue irrespective of wound size. Larger ulcers were associated with higher rates of comorbidities and vascular abnormalities. Machine VAC was predominantly used in larger wounds.

Conclusion: VAC therapy is effective across all wound sizes, with machine-based VAC showing superior outcomes in larger ulcers. Tailoring VAC modality according to wound size and patient profile optimizes healing outcomes and resource use.

Keywords: Chronic ulcers, Negative pressure wound therapy, VAC therapy, Machine-based VAC, Wall-mounted VAC, Wound healing.

INTRODUCTION

Chronic non-healing ulcers represent a significant clinical challenge, particularly in individuals with diabetes mellitus, and have emerged as a major public health concern in India. Defined as wounds that fail to progress through the normal phases of healing within a period of three months, these ulcers often require prolonged medical intervention and are associated with substantial morbidity and risk of limb amputation if left untreated or ineffectively managed.[1,2] Chronic ulcers are defined as wounds that fail to heal within three months despite appropriate treatment and care, often due to impaired vascular supply, infection, neuropathy, or systemic comorbidities. Clinically, such ulcers often present with persistent pain, foul-smelling discharge, slough or necrotic tissue, irregular wound margins, delayed granulation, and in advanced cases, surrounding cellulitis or signs of ischemia. Among these, diabetic foot ulcers (DFUs) form a prominent subset, contributing significantly to hospital admissions and healthcare burden.[3]

The pathophysiology of chronic ulcers in diabetics is multifactorial, involving peripheral neuropathy, peripheral arterial disease, and impaired immune function, all of which impair wound healing and increase susceptibility to infection.[4] In India, the burden of diabetes is among the highest globally, and as a result, the incidence of DFUs and related complications has seen a steady rise, with substantial implications for patient quality of life and healthcare expenditure.[5]

Negative pressure wound therapy (NPWT), commonly known as Vacuum-Assisted Closure (V.A.C), has emerged as an advanced modality to accelerate wound healing in chronic ulcers. It facilitates wound bed preparation by removing exudate, reducing edema, enhancing perfusion, and promoting granulation tissue formation.[6,7] While conventional NPWT systems utilizing portable machines are well studied and widely implemented globally, in resource-limited settings like India, the use of hospital wall-mounted vacuum systems has also gained traction due to their relative affordability and accessibility, however, limited data exist comparing different VAC systems across varying wound sizes. The present study is aimed to validate and compare the effectiveness of machine-based and wall-mounted VAC therapies, with the goal of helping clinicians choose suitable treatments according to patient needs and wound characteristics.[8]

However, comparative data evaluating the efficacy and cost-effectiveness of machine-based versus wall-mounted vacuum therapy in Indian settings remain sparse. The financial constraints, variable access to healthcare resources, socio-cultural influences, and disparities in wound care literacy among patients in India necessitate a contextual evaluation of these treatment modalities.[9,10] Furthermore, understanding wound healing dynamics within the framework of Indian demographics and healthcare infrastructure can significantly inform clinical practice. Conventional treatment modalities include wound debridement, infection control, appropriate dressings, offloading, and optimization of systemic conditions such as glycemic control. More advanced methods like skin grafts, hyperbaric oxygen therapy, and negative pressure wound therapy (VAC) are now increasingly used to accelerate healing.

This study, conducted at KIMS Hospital, Bengaluru, aims to evaluate and compare the healing outcomes and cost-effectiveness of machine vacuum-assisted therapy versus wall-mounted vacuum therapy in patients with chronic non-healing ulcers. It aimed to measure and analyze clinical parameters such as rate of wound size reduction, degree of wound contraction, and granulation tissue formation using established grading systems like Wagner's classification.[11] The study hopes to offer evidence-based recommendations that can enhance wound management strategies and patient outcomes.

MATERIALS AND METHODS

This prospective observational study was conducted over a period of 12 months in the Department of General Surgery at Kempegowda Institute of Medical Sciences and Research Centre (KIMS), Bengaluru, India. The objective was to evaluate and compare wound healing outcomes in chronic non-healing ulcers treated with different vacuum-assisted closure (VAC) systems, categorized based on initial wound size.

A total of 180 patients aged >18 years with chronic non-healing ulcers (non-responding for more than 3 months) were enrolled. Patients were divided into three groups based on **initial wound size** at presentation:

- **Group A (n = 58):** Wound size ≤ 50 cm²
- **Group B (n = 60):** Wound **size** 51–100 cm²
- **Group C (n = 62):** Wound **size**> 100 cm²

This classification was used to compare the clinical outcomes of VAC therapy and dressing methods according to the severity and extent of the ulcer.

Inclusion Criteria

- Patients >18 years of age
- Chronic non-healing ulcers of any etiology
- Wound size measurable and falling into one of the three defined categories
- Admitted under the Department of General Surgery at KIMS Hospital

Exclusion Criteria

- Healing or granulating ulcers at the time of evaluation
- Ulcers associated with underlying osteomyelitis or fracture
- Malignant ulcers
- Patients with occlusive peripheral vascular disease (confirmed by Doppler)
- Patients unwilling to consent for the study

Clinical Evaluation and Management Protocol

A detailed clinical history and examination were performed for all patients, along with radiological evaluation to assess the extent of the ulcer and associated conditions. This was followed by wound debridement to remove slough and necrotic tissue. After debridement, vacuum-assisted closure (VAC) dressing was applied for two cycles, each cycle lasting for five days.Culture swabs were collected for microbiological analysis, and Doppler studies of the lower limb vasculature were conducted to assess arterial and venous flow.Each patient received either wall-mounted or machine-based VAC therapy depending on availability, cost considerations, and patient preference. Wound healing was evaluated after the two VAC therapy cycles for parameters including wound contraction, rate of contracture, and granulation tissue formation.

VAC Application Methods

- **Wall-Mounted VAC Therapy:** Applied at a constant negative pressure of -125 mmHg (range -40 to -400 mmHg). A 5000 mL tank collected exudate, emptied periodically. Dressings were changed every 5 days.
- **Machine-Based VAC Therapy:** Delivered intermittent negative pressure (-80 to -150 mmHg) in 15-second on/off cycles using a portable machine. Canisters of 500–1000 mL were replaced when full. Dressings were also changed every 5 days.

The type of VAC therapy (machine-based or wall-mounted) was analyzed in relation to wound size, rate of wound contraction, appearance of granulation tissue, associated comorbidities, and vascular findings.Weanalysed potential selection bias due to preferential use of machine VAC in larger wounds by performing (i) wound-size–stratified analyses, (ii) multivariable regression adjusting for baseline wound size, vascular Doppler category, diabetes status, age, and sex, and (iii) a propensity score–based analysis (inverse probability weighting/matching) to balance baseline covariates between VAC types. We also assessed VAC type × wound size interaction.

Granulation Tissue Evaluation

Granulation tissue was assessed using Wagner's grading system:

Grade	Description
Grade 1	No granulation tissue
Grade 2	<25% wound covered with granulation tissue
Grade 3	25–74% wound covered with granulation tissue
Grade 4	75–100% wound covered with granulation tissue

Outcome Measures

Primary outcome parameters included:

- Change in wound size (cm²)
- Rate of wound contraction per VAC cycle
- Grade of granulation tissue after treatment

Secondary parameters included:

- Distribution of comorbidities (e.g., T2DM, HTN, IHD)
- Peripheral vascular flow patterns (biphasic/monophasic, atheromatous changes)
- Type and frequency of VAC source usage

Statistical Analysis

Data were analyzed using SPSS version 25. Descriptive statistics were used to summarize demographic and clinical characteristics. Continuous variables were reported as mean ± standard deviation and compared using ANOVA. Categorical data were compared using the Chi-square test. A p-value <0.05 was considered statistically significant.

RESULTS

This prospective observational study included a total of 180 patients with chronic non-healing ulcers, who were categorized into three groups based on initial wound size: Group A (≤50 cm², n = 58), Group B (51–100 cm², n = 60), and Group C (>100 cm², n = 62). Before adjustment, machine VAC recipients had larger baseline wounds and more vascular abnormalities. After propensity weighting, covariate balance improved (all standardized mean differences <0.1), and the association between VAC type and outcomes remained directionally consistent.

The mean age of patients showed a progressive increase across the groups, with Group A having a mean age of 46.48 ± 9.86 years, Group B 49.42 ± 12.21 years, and Group C 53.03 ± 13.75 years. Most patients belonged to the 38–57 years age group, which was particularly predominant in Group A (79.31%). [Table 1] Gender distribution revealed a male predominance in all groups, with the highest proportion observed in Group C (80.64%), followed by Group B (60%) and Group A (53.44%). Wound size reduction was a key outcome measured across two VAC therapy cycles. The baseline wound size, as expected, was significantly different between groups, with Group A presenting with a mean of 32.90 ± 10.74 cm², Group B with 75.33 ± 14.05 cm², and Group C with 276.26 ± 167.63 cm² (p = 0.01). During subsequent assessments after VAC therapy, all groups demonstrated progressive wound size reduction. Group C exhibited the greatest decrease in wound dimensions, followed by Group B and Group A. [Table 2] The rate of wound contraction per cycle was also significantly higher in Group C, with contracture rates of 8.15 ± 4.62 cm² and 4.94 ± 4.54 cm² across the two cycles, respectively. In comparison, Group B showed moderate contraction (2.50 ± 2.30 and 1.52 ± 1.53 cm²), and Group A had the slowest rate (1.31 ± 1.25 and 1.47 ± 1.05 cm²). These differences were statistically significant (p < 0.001), indicating that VAC therapy produced more pronounced benefits in larger wounds.

Granulation tissue formation, assessed using Wagner grading, revealed that the majority of patients across all groups ultimately developed Grade 4 granulation tissue, denoting 75–100% coverage. Grade 4 granulation was observed in 96.55% of patients in Group A, 96.67% in Group B, and 95.1% in Group C. While granulation grades appeared similar across groups, statistical analysis did not show a significant difference (p > 0.05). [Table 3] This suggested that granulation tissue formation was largely consistent across varying wound sizes when managed with vacuum-assisted therapy.

Peripheral arterial Doppler studies highlighted notable differences in vascular profiles among the groups. Normal biphasic or triphasic arterial flow was observed most frequently in Group A (77.59%), followed by Group B (53.33%) and Group C

(38.71%). Atheromatous wall irregularities were increasingly prevalent in patients with larger ulcers, found in 18.96% of Group A, 45% of Group B, and 56.45% of Group C. Additionally, more severe flow abnormalities, such as monophasic flow and diffuse atheromatous changes, were limited to Group C, further supporting a possible association between impaired vascular supply and larger wound burden ($p = 0.02$).

The distribution of comorbidities was also assessed across groups. Type 2 diabetes mellitus (T2DM) was the most common comorbidity, present in 32.76% of Group A, 40% of Group B, and 56.45% of Group C. A combination of T2DM and hypertension was also more frequently noted in patients with larger wound sizes. However, these differences did not reach statistical significance ($p = 0.98$). Interestingly, the proportion of patients without any comorbidity declined with increasing wound size, from 32.76% in Group A and 33.33% in Group B to only 16.13% in Group C.

The type of vacuum-assisted closure system used varied significantly among the three groups ($p = 0.05$). Wall-mounted VAC systems were more frequently used in patients with smaller wounds (79.31% in Group A), whereas machine-based VAC systems were predominantly used in Group B (53.33%) and Group C (46.77%).

Table 1: Demographic and Clinical Profile

Parameter	Group A (≤50 cm²)	Group B (51–100 cm²)	Group C (>100 cm²)
Mean Age (years)	46.48 ± 9.86	49.42 ± 12.21	53.03 ± 13.75
Male (%)	53.44%	60.00%	80.64%
Female (%)	46.55%	40.00%	19.36%
T2DM (%)	32.76%	40.00%	56.45%
HTN (%)	18.97%	6.67%	1.61%
No Comorbidity (%)	32.76%	33.33%	16.13%

Table 2: Wound Size Distribution in study population

Wound Size	Group A (Mean ± SD)	Group B (Mean ± SD)	Group C (Mean ± SD)	p-value
Size 0	32.90 ± 10.74	75.33 ± 14.05	276.26 ± 167.63	0.01
Size 1	31.59 ± 10.44	73.17 ± 13.41	269.73 ± 165.81	0.01
Size 2	30.12 ± 10.23	71.65 ± 13.16	264.79 ± 166.28	0.01

ANOVA test

Table 3: Granualtion tissue Distribution in study population

Stage	Tissue Type	Group A Count	Group A (%)	Group B Count	Group B (%)	Group C Count	Group C (%)	p-value
1	Tissue 0	7	12.07	10	16.67	17	27.42	0.23
	Tissue 1	0	0	0	0	0	0	-
	Tissue 2	0	0	0	0	0	0	-
2	Tissue 0	38	65.52	34	56.67	33	53.23	0.25
	Tissue 1	1	1.72	0	0	0	0	-
	Tissue 2	0	0	0	0	0	0	-
3	Tissue 0	13	22.41	16	26.67	12	19.35	0.96
	Tissue 1	23	39.66	21	35.00	32	51.61	0.70
	Tissue 2	2	3.45	2	3.33	3	4.84	0.65
4	Tissue 0	0	0	0	0	0	0	-
	Tissue 1	34	58.62	39	65.00	30	48.39	0.89
	Tissue 2	56	96.55	58	96.67	59	95.1	0.06

Chi-Square Test

DISCUSSION

This prospective observational study assessed and compared healing outcomes across three groups of chronic non-healing ulcers stratified by wound size. Our results demonstrated that VAC therapy—both machine-based and wall-mounted—was effective across all wound sizes, with the greatest contraction and healing observed in larger ulcers (>100 cm²). These findings are consistent with a growing body of evidence supporting the use of negative pressure wound therapy (NPWT) in diabetic foot ulcers (DFUs) and chronic wounds. Since treatment was not assigned randomly and machine VAC was used more often for larger or more complex ulcers, the results may be influenced by this treatment choice. We used stratified, adjusted, and propensity-weighted analyses to reduce this problem, but some hidden bias may still remain.

A considerable proportion of patients with diabetes mellitus develop DFUs, with incidence rates ranging from 1% in Western populations to as high as 11% in African populations. DFUs account for nearly 85% of non-traumatic lower limb amputations and are associated with nearly double the mortality rate compared to diabetic patients without foot ulcers.[11-13] In our study, the proportion of patients with T2DM progressively increased with wound size, from 32.76% in Group A to 56.45% in Group C, onfirming the association between diabetes and chronic ulcer burden.

Our study found that the rate of wound contraction was significantly higher in larger ulcers, with Group C showing a reduction of 8.15 ± 4.62 cm² and 4.94 ± 4.54 cm² across two VAC cycles. This observation aligns with the findings of Sangama et al,[14] who demonstrated that VAC therapy resulted in significantly faster healing in ulcers ≥10 cm compared to conventional dressing, with P = 0.0042. They attributed this to the greater macrodeformation forces generated over wider wound beds, enhancing cellular proliferation, angiogenesis, and contraction.[8,15]

Our data also showed rapid granulation formation, with >95% of patients across all groups achieving Wagner Grade 4 granulation after two VAC cycles. Sangama et al. similarly reported that the mean time to achieve 75–100% granulation was significantly shorter in the VAC group (23.33 days) versus conventional dressing (32.15 days), P < 0.0001.[14] Armstrong et al. showed a similar trend, where median time to achieve 76–100% granulation was halved with VAC therapy (42 vs. 84 days).[5]

Singh et al. further supported these findings, noting complete granulation within 15.1 days in the VAC group compared to 21.5 days in the control group.[8]

The present study also confirmed that VAC therapy was particularly effective in ischemic or atheromatous limbs, as seen in Group C, which had the lowest proportion of normal Doppler flow (38.71%) and the highest incidence of wall irregularities (56.45%). Despite these vascular limitations, the group showed significant wound contraction and granulation, highlighting VAC's potential to overcome perfusion challenges through enhanced microvascular angiogenesis.[16-18]

Comorbidities such as T2DM and HTN did not significantly differ across groups, though the burden was numerically greater in larger ulcers. Prior studies, including by Nain et al., demonstrated that VAC led to greater reduction in ulcer area in DFUs (16.14 cm² vs. 5.98 cm² in control),[2] which supports our finding that larger wounds responded more dramatically to NPWT. Similarly, Liu et al., in a meta-analysis, confirmed that VAC significantly reduces DFU size and improves healing rates over standard dressings.[17]

In our study wall-mounted VAC was more frequently used in smaller wounds and was associated with minimal patient discomfort. Sangama et al. reported significantly lower pain scores in VAC-treated patients at week 3 (VAS score 3 vs. 4, P = 0.004), likely due to fewer dressing changes and better wound coverage.[14] Other studies have highlighted that gauze-based NPWT, as used in many wall-mounted systems, may cause less pain than foam-based devices due to reduced adherence to granulating surfaces.[19,20]

Importantly, no significant bleeding complications were observed in our study, which aligns with observations by Singh et al. and Nather et al., who emphasized that proper hemostasis and pressure modulation can prevent hemorrhagicevents.[7,8] VAC therapy should be applied with caution only after adequate debridement and vascular assessment, as improper technique may trap infection or cause mechanical trauma.

Overall, our findings align closely with those of prior Indian and global studies. VAC therapy proved superior in terms of wound contraction, granulation formation, and patient comfort, particularly in larger and more complex ulcers. Compared to conventional dressing, VAC offers multiple advantages through its mechanisms of macro- and micro-deformation, enhanced cellular signaling, and optimized wound environment.

In our study, the greatest wound contraction was observed in Group C (>100 cm²), where machine VAC therapy yielded the most significant outcomes across two cycles. Group B (51–100 cm²) showed moderate contraction with no major difference between machine and wall-mounted VAC, suggesting an equivocal response. Group A (≤50 cm²) demonstrated the least contraction, with outcomes being similar across both VAC modalities. These findings highlight that the benefit of machine VAC becomes particularly evident in larger ulcers, while smaller wounds can be effectively managed with wall-mounted VAC.

CONCLUSION

VAC therapy shows effective outcomes across all wound sizes, but larger wounds demonstrate improved outcomes with machine-based VAC therapy. In contrast, Group B ulcers showed an equivocal response to both treatment modalities, similar to Group A, where outcomes were largely comparable between machine-based and wall-mounted VAC systems. Therefore, tailoring the choice of VAC therapy according to wound size, patient comorbidities, and vascular status remains essential for optimizing clinical outcomes. VAC therapy shows effective outcomes across all wound sizes; however, Group C patients with larger wounds had the most pronounced benefits with machine VAC therapy. In Group B wounds, outcomes were comparable between machine and wall-mounted VAC, while Group A wounds responded similarly to both modalities. These findings provide improved insight into tailoring VAC therapy according to patient needs and wound characteristics, ensuring resource optimization and better clinical outcomes.

Limitations

This study had several limitations. It was a single-center study, limiting generalizability to wider populations. Group allocation was non-randomized, introducing potential selection bias. Key factors such as nutritional status, glycemic control, and offloading compliance were not systematically assessed. The short follow-up period of two VAC cycles may not reflect long-term outcomes or recurrence. Additionally, variability in operator technique and dressing application may have influenced the results.

REFERENCES

1. Novak A, Khan WS, Palmer J. The evidence-based principles of negative pressure wound therapy in trauma & orthopedics. Open Orthop J. 2014 Jun 27;8(1):168–77.
2. Nain PS, Uppal SK, Garg R, Bajaj K, Garg S. Role of negative pressure wound therapy in healing of diabetic foot ulcers. J Surg Tech Case Rep. 2011;3(1):17–22.
3. Hasan MY, Teo R, Nather A. Negative-pressure wound therapy for management of diabetic foot wounds: a review of the mechanism of action, clinical applications, and recent developments. Diabet Foot Ankle. 2015;6:27618.
4. Lone AM, Zaroo MI, Laway BA, Pala NA, Bashir SA, Rasool A. Vacuum-assisted closure versus conventional dressings in the management of diabetic foot ulcers: a prospective case-control study. Diabet Foot Ankle. 2014;5(1):23345.
5. Armstrong DG, Lavery LA; Diabetic Foot Study Consortium. Negative pressure wound therapy after partial diabetic foot amputation: a multicentre, randomised controlled trial. Lancet. 2005 Nov 12;366(9498):1704–10.
6. Johari H, Kazemzadeh G, Modaghegh MH, Ravari H, Sangaki A, Shahrodi M, et al. Comparison of vacuum-assisted closure and moist wound dressing in the treatment of diabetic foot ulcers. J CutanAesthet Surg. 2013;6(1):17.
7. Nather A, Hong NY, Lin WK, Sakharam JA. Effectiveness of bridge V.A.C. dressings in the treatment of diabetic foot ulcers. Diabet Foot Ankle. 2011;2(1):5893.
8. Singh B, Sharma D, Jaswal KS. Comparison of negative pressure wound therapy vs. conventional dressings in the management of chronic diabetic foot ulcers in a tertiary care hospital in North India. Int J Sci Res. 2017 Aug;6(8):948–53.
9. Armstrong DG, Wrobel J, Robbins JM. Guest editorial: are diabetes-related wounds and amputations worse than cancer? Int Wound J. 2007 Dec;4(4):286–7.
10. Pecoraro RE, Reiber GE, Burgess EM. Pathways to diabetic limb amputation: basis for prevention. Diabetes Care. 1990 May;13(5):513–21.
11. Ibrahim A. IDF clinical practice recommendation on the diabetic foot: a guide for healthcare professionals. Diabetes Res ClinPract. 2017;127:285–7.
12. Shojaiefard A, Khorgami Z, Larijani B. Independent risk factors for amputation in diabetic foot. Int J Diabetes Dev Ctries. 2008;28:32–7.
13. Robbins JM, Strauss G, Aron D, Long J, Kuba J, Kaplan Y, et al. Mortality rates and diabetic foot ulcers: is it time to communicate mortality risk to patients with diabetic foot ulceration? J Am Podiatr Med Assoc. 2008;98:489–93.
14. James SMD, Sureshkumar S, Elamurugan TP, Debasis N, Vijayakumar C, Palanivel C. Comparison of vacuum-assisted closure therapy and conventional dressing on wound healing in patients with diabetic foot ulcer: a randomized controlled trial. Niger J Surg. 2019 Jan–Jun;25(1):14–20. doi:10.4103/njs.NJS_14_18.
15. Orgill DP, Manders EK, Sumpio BE, Lee RC, Attinger CE, Gurtner GC, et al. The mechanisms of action of vacuum assisted closure: more to learn. Surgery. 2009;146:40–51.
16. Wiegand C, White R. Microdeformation in wound healing. Wound Repair Regen. 2013;21:793–9.
17. Lu F, Ogawa R, Nguyen DT, Chen B, Guo D, Helm DL, et al. Microdeformation of three-dimensional cultured fibroblasts induces gene expression and morphological changes. Ann Plast Surg. 2011;66:296–300.
18. Labler L, Rancan M, Mica L, Härter L, Mihic-Probst D, Keel M, et al. Vacuum-assisted closure therapy increases local interleukin-8 and vascular endothelial growth factor levels in traumatic wounds. J Trauma. 2009;66:749–57.
19. Dorafshar AH, Franczyk M, Gottlieb LJ, Wroblewski KE, Lohman RF. A prospective randomized trial comparing subatmospheric wound therapy with a sealed gauze dressing and the standard vacuum-assisted closure device. Ann Plast Surg. 2012;69:79–84.
20. Fraccalvieri M, Ruka E, Bocchiotti MA, Zingarelli E, Bruschi S. Patient's pain feedback using negative pressure wound therapy with foam and gauze. Int Wound J. 2011;8:492–9.