

AN OBSERVATIONAL STUDY TO ASSESS THE EFFECTIVENESS OF INTERMITTENT VS CONTINUOUS NEGATIVE PRESSURE WOUND THERAPY IN THE HEALING OF DIABETIC FOOT ULCERS

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Abstract

Background: Diabetic foot ulcers (DFUs) are among the most serious complications of diabetes mellitus and are associated with delayed wound healing, infection, prolonged hospitalization, and increased risk of lower-limb amputation. Negative pressure wound therapy (NPWT) has emerged as an effective adjunct in DFU management. While continuous NPWT is commonly used, intermittent NPWT has been proposed to enhance wound healing through improved tissue perfusion and cellular stimulation. However, comparative evidence between these two modalities remains limited. Aim of the study was to compare the effectiveness of intermittent versus continuous negative pressure wound therapy in the healing of diabetic foot ulcers with respect to wound contraction, granulation tissue formation, wound closure time, and duration of hospital stay. **Materials and Methods:** This prospective observational study was conducted over 18 months at a tertiary care center. Sixty patients with Wagner grade 1 and 2 diabetic foot ulcers were enrolled and divided into two groups: Group A (continuous NPWT, n = 30) and Group B (intermittent NPWT, n = 30). After surgical debridement, NPWT was applied at -75 to -125 mmHg either continuously (Group A) or intermittently (1 hour every 3 hours; Group B). Patients were followed up to 12 weeks. Outcomes assessed included wound contraction percentage, time to wound closure, granulation tissue formation, and length of hospital stay. Statistical analysis was performed using IBM SPSS version 24. **Results:** Baseline characteristics were comparable between the two groups. Wound healing at 12 weeks was higher in the intermittent NPWT group compared to the continuous NPWT group (86.67% vs 73.33%). Intermittent NPWT demonstrated significantly greater wound contraction at 6 weeks (76.63% vs 68.45%, p = 0.001) and 12 weeks (93.84% vs 88.16%, p = 0.01). Mean wound closure time was significantly shorter in the intermittent group (72.65 ± 14.92 days) compared to the continuous group (82.71 ± 16.75 days; p = 0.0001). The duration of hospital stay was slightly shorter in the intermittent group but did not reach statistical significance. **Conclusion:** Intermittent NPWT is more effective than continuous NPWT in promoting wound contraction and accelerating wound closure in diabetic foot ulcers. It represents a superior modality for optimizing DFU healing outcomes.

Keywords: Diabetic foot ulcer; Negative pressure wound therapy; Intermittent NPWT; Continuous NPWT; Wound healing; Vacuum-assisted closure



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INTRODUCTION

Diabetes mellitus (DM) is a chronic metabolic disorder characterized by persistent hyperglycemia resulting from defects in insulin secretion, insulin action, or both. It has emerged as a major global health challenge, with the International Diabetes Federation estimating that 537 million adults were living with diabetes in 2021, a figure projected to increase to 643 million by 2030 and 783 million by 2045 (1). Among the most serious and prevalent complications of diabetes is the development of diabetic foot ulcers (DFUs), with approximately 15–25% of individuals with diabetes expected to develop a foot ulcer during their lifetime. Notably, DFUs precede nearly 85% of diabetes-related lower limb amputations (2).

The pathogenesis of DFUs is multifactorial, commonly involving peripheral neuropathy, peripheral arterial disease, foot deformities, minor repetitive trauma, and impaired immune function. These ulcers are associated with delayed wound healing, high recurrence rates, and an increased risk of infection, sepsis, and lower extremity amputation (3). Beyond the clinical consequences, DFUs impose a substantial economic and psychosocial burden, leading to prolonged hospital stays, frequent outpatient visits, long-term antibiotic use, reduced quality of life, and increased mortality (4).

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Management of diabetic foot ulcers is complex and necessitates a multidisciplinary approach encompassing optimal glycemic control, infection management, pressure offloading, vascular assessment, and advanced wound care techniques. Among recent advances, Negative Pressure Wound Therapy (NPWT) has gained widespread acceptance as an effective modality in DFU management. NPWT involves the application of controlled subatmospheric pressure to the wound bed via a sealed dressing connected to a vacuum device, facilitating removal of exudate, reduction of edema, enhancement of local perfusion, and stimulation of granulation tissue formation (5).

Although continuous NPWT remains the most commonly employed mode, intermittent NPWT characterized by alternating cycles of negative pressure and atmospheric pressure—has attracted increasing interest. Intermittent therapy is postulated to enhance wound healing by improving tissue oxygenation and promoting cellular proliferation through cyclic mechanical stimulation (6). Furthermore, intermittent NPWT may offer advantages in terms of patient comfort and a reduced risk of tissue hypoxia associated with sustained negative pressure (7).

Despite these theoretical benefits, evidence comparing the clinical efficacy of intermittent versus continuous NPWT in diabetic foot ulcer healing remains limited and inconclusive. While some studies report faster granulation tissue formation and reduced healing time with intermittent NPWT, others demonstrate no significant difference between the two modalities (8). Additionally, factors such as wound size, depth, presence of infection, and vascular status may influence treatment outcomes and should be considered when selecting the appropriate NPWT mode.

In resource-limited healthcare settings, where diabetic foot ulcers are frequently underdiagnosed or inadequately treated due to limited access to advanced wound care, identifying the most effective NPWT modality is of critical importance. Optimizing wound healing can reduce infection rates and amputations, improve patient mobility and independence, shorten hospital stays, and decrease the overall economic burden on healthcare systems (9). Given the growing global burden of diabetic foot complications, further research is warranted to clarify the comparative benefits of NPWT application modes. This observational study aims to evaluate and compare the healing outcomes of intermittent versus continuous NPWT in patients with diabetic foot ulcers, with the goal of informing more effective and individualized wound care strategies.

The aim of this study is to compare the effectiveness of intermittent and continuous negative pressure wound therapy in the healing of diabetic foot ulcers. Specifically, the study seeks to evaluate and compare

both modalities with respect to wound contraction, granulation tissue formation, time to wound closure, and duration of hospital stay.

MATERIALS AND METHODS

Study Design and Setting

This was a prospective observational study conducted over a period of 18 months, from April 2023 to September 2024. The study was carried out in the Department of General Surgery at Deccan College of Medical Sciences, Owaisi Hospital & Research Centre, and Princess Esra Hospital, Hyderabad.

Study Population and Sample Size

A total of 60 patients diagnosed with diabetic foot ulcers were included in the study. The study population was divided into two equal groups: Group 1 comprised 30 patients treated with continuous negative pressure wound therapy (NPWT), while Group 2 included 30 patients managed with intermittent NPWT.

The sample size was calculated based on a reported prevalence of diabetic foot ulcers of approximately 7%. The standard formula for sample size calculation, $n = 4pq / d^2$,

was used, where p represents the prevalence (7), q equals $100 - p$ (93), and d denotes the allowable error (5). Substitution of these values yielded a required sample size of 60 patients for the present study.

Inclusion Criteria

Patients with diabetic foot ulcers were included if they fulfilled the following criteria: age between 20 and 70 years; Wagner's grade 1 or grade 2 ulcers; and ulcer surface area ranging from 25 cm² to 200 cm².

Exclusion Criteria

Patients were excluded from the study if they had evidence of septicemia, osteomyelitis, ulcers secondary to venous insufficiency, malignant transformation within the wound, or if they were receiving corticosteroids, immunosuppressive agents, or chemotherapy. Patients with significant pre-existing cardiovascular, pulmonary, or immunological diseases were also excluded.

Data Collection

Baseline demographic data including age and sex were recorded, and a detailed clinical examination was performed for all patients using a predesigned proforma. Routine laboratory investigations such as complete blood count, renal function tests, liver function tests, and glycated hemoglobin (HbA1c) were performed in all cases. Pus culture and sensitivity testing, along with radiographic evaluation of the affected part, were conducted to assess infection and exclude underlying osteomyelitis. Peripheral pulses were palpated to rule out peripheral vascular disease. Blood glucose levels were strictly monitored and

controlled using insulin and/or oral hypoglycemic agents as required.

Wound Assessment and Follow-up

Ulcers were graded according to Wagner’s classification system. Wound inspection was performed every three days to assess healing progress, and surgical debridement was carried out as needed to remove necrotic tissue and slough. Pus culture and antibiotic sensitivity testing were repeated every three days, and antibiotic therapy was modified accordingly based on culture results. Wounds were monitored until surgical closure, spontaneous closure, or completion of 15 days of therapy, whichever occurred earlier.

Intervention Protocol

Following initial sharp surgical debridement under aseptic conditions, foam-based dressings were applied to the wound bed and covered with an adhesive drape to ensure an airtight seal. An evacuation tube embedded within the foam was connected to a vacuum device, and subatmospheric pressure ranging from -75 to -125 mmHg was applied.

In Group 1, continuous NPWT was administered continuously for 72 hours. In Group 2, intermittent NPWT was applied for one hour at three-hour intervals. This protocol was maintained throughout the treatment period. All patients received standardized wound care and antibiotic therapy during hospitalization.

Outcome Parameters

The primary parameters assessed in this study included wound contraction, granulation tissue formation, time to wound closure, and duration of hospital stay.

Ethical Considerations and Follow-up

Approval for the study was obtained from the Institutional Ethical Committee prior to commencement. Written informed consent was obtained from all participants. Following wound closure, patients were followed regularly: weekly for the first month, biweekly during the second month, and monthly thereafter until the end of the study period.

Statistical Analysis

Data were entered into Microsoft Excel 2010 and analyzed using IBM SPSS Statistics for Windows, version 24. Qualitative variables were expressed as frequencies and percentages, while quantitative variables were summarized using mean and standard deviation. Associations between qualitative variables were assessed using the Chi-square test with continuity correction for 2 × 2 tables, and Fisher’s exact test was employed when expected cell counts were small. Quantitative variables were compared between the continuous and intermittent NPWT groups using the paired t-test after confirming normality of data distribution. A p value of less than 0.05 was considered statistically significant.

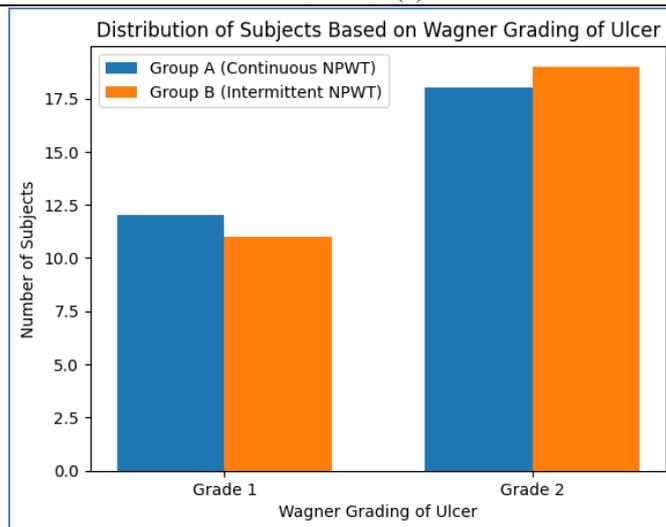
RESULTS

Table 1: Distribution of Study Subjects According to Age Group and Sex

Variable	Category	Group A (Continuous NPWT) N (%)	Group B (Intermittent NPWT) N (%)
Age group (years)	31–40	2 (6.67)	1 (3.33)
	41–50	7 (23.33)	8 (26.67)
	51–60	13 (43.33)	12 (40.00)
	61–70	8 (26.67)	9 (30.00)
Sex	Male	18 (60.00)	17 (56.67)
	Female	12 (40.00)	13 (43.33)
Total		30 (100)	30 (100)

Table 1 summarizes the distribution of study subjects according to age group and sex in both treatment groups. The age distribution was comparable between Group A (continuous NPWT) and Group B (intermittent NPWT), with the majority of patients in both groups belonging to the 51–60-year age group, followed by those aged 61–70 years. Very few patients were younger than 40 years, indicating that diabetic foot ulcers were predominantly observed in middle-aged and elderly individuals. The sex distribution was also similar between the two groups, with a male predominance in both Group A (60%) and Group B (56.67%). Overall, there were no notable differences in age or sex distribution between the groups, suggesting good baseline comparability and minimizing the influence of these demographic factors on the comparison of treatment outcomes.

Figure 1: Distribution of Subjects Based on Wagner Grading of Ulcer



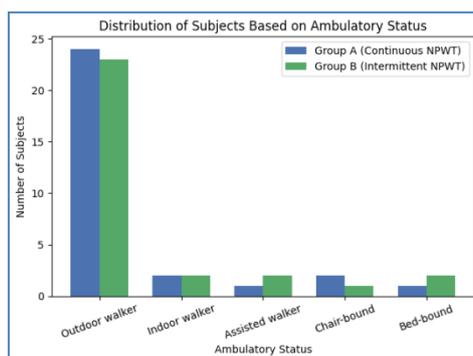
The Figure 1 illustrates the distribution of study subjects according to Wagner grading of diabetic foot ulcers in both treatment groups. In Group A (continuous NPWT), 40% of patients had Grade 1 ulcers and 60% had Grade 2 ulcers, while in Group B (intermittent NPWT), 36.67% had Grade 1 ulcers and 63.33% had Grade 2 ulcers. Grade 2 ulcers constituted the majority in both groups, indicating that most patients presented with moderately severe ulcers. The nearly similar distribution of Wagner grades between the two groups demonstrates good baseline comparability with respect to ulcer severity, thereby minimizing bias and allowing a valid comparison of healing outcomes between continuous and intermittent NPWT.

Table 2: Distribution of Subjects Based on Comorbid Conditions

Comorbid Conditions	Group A (Continuous NPWT) N (%)	Group B (Intermittent NPWT) N (%)
Diabetes Mellitus (DM)	8 (26.67)	9 (30.00)
Diabetes Mellitus with Hypertension (DM + HTN)	11 (36.67)	13 (43.33)
Diabetes Mellitus with Vascular Disease (DM + Vascular Disease)	9 (30.00)	8 (26.67)
Total	30 (100)	30 (100)

Table 2 depicts the distribution of comorbid conditions among the study subjects in both groups. The pattern of comorbidities was comparable between Group A (continuous NPWT) and Group B (intermittent NPWT). Diabetes mellitus with hypertension was the most common comorbidity in both groups, observed in 36.67% of Group A and 43.33% of Group B patients, followed by diabetes mellitus with vascular disease. A smaller proportion of patients had diabetes mellitus alone. The similar distribution of associated comorbid conditions between the two groups indicates good baseline comparability and suggests that systemic disease burden was unlikely to have significantly influenced the comparative wound healing outcomes of the two NPWT modalities.

Figure 2: Distribution of Subjects Based on Ambulatory Status



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The figure 2 shows the distribution of subjects based on ambulatory status in both treatment groups. In Group A (continuous NPWT) and Group B (intermittent NPWT), the majority of patients were outdoor walkers, indicating preserved baseline mobility in most participants. A smaller proportion of patients were indoor walkers or required assisted ambulation, while very few were chair-bound or bed-bound in either group. The overall ambulatory status was comparable between the two groups, suggesting similar functional status at baseline. This balanced distribution minimizes the influence of mobility-related factors on wound healing outcomes and supports a valid comparison of the effectiveness of continuous and intermittent NPWT.

Table 3: Comparison of Wound-Related Characteristics Between the Study Groups

Wound-Related Characteristics	Group A (Continuous NPWT) Mean \pm SD	Group B (Intermittent NPWT) Mean \pm SD	P value
SEWSS (DFU score)	15.81 \pm 2.62	16.69 \pm 2.48	0.173
Initial wound size (cm ²)	23.86 \pm 23.15	24.68 \pm 22.57	0.090
Initial wound volume (cm ³)	13.54 \pm 14.17	12.44 \pm 13.47	0.010

Table 3 compares the baseline wound-related characteristics between the two study groups. The mean SEWSS (Site, Exudate, Wound Size, and Severity) diabetic foot ulcer score was slightly higher in Group B (intermittent NPWT) than in Group A (continuous NPWT); however, this difference was not statistically significant, indicating comparable overall wound severity at baseline. Similarly, the initial wound surface area did not differ significantly between the groups, suggesting a comparable burden of ulcer size. In contrast, the initial wound volume was significantly lower in the intermittent NPWT group compared to the continuous NPWT group. Although statistically significant, the difference in mean wound volume was small and is unlikely to be of major clinical relevance. Overall, these findings indicate that both groups were largely comparable with respect to baseline wound characteristics, supporting the validity of subsequent outcome comparisons.

Table 4: Comparison of Wound Healing Status at 6 and 12 Weeks Between Study Groups

Time Point	Wound Healing Status	Group A (Continuous NPWT) N (%)	Group B (Intermittent NPWT) N (%)
6 weeks	Yes	11 (36.67)	14 (46.67)
	No	19 (63.33)	16 (53.33)
12 weeks	Yes	22 (73.33)	26 (86.67)
	No	8 (26.67)	4 (13.33)
Total (each group)		30 (100)	30 (100)

Table 4 compares the wound healing status of patients at 6 weeks and 12 weeks between the two study groups. At 6 weeks, a higher proportion of patients in Group B (intermittent NPWT) achieved wound healing compared to Group A (46.67% vs 36.67%), although a considerable number of patients in both groups had not yet healed. By 12 weeks, wound healing rates increased substantially in both groups; however, Group B continued to demonstrate a higher healing proportion than Group A (86.67% vs 73.33%). These findings indicate progressive wound healing over time with NPWT in both groups, with intermittent NPWT showing a consistently better healing trend compared to continuous NPWT.

Table 5: Comparison of Wound Healing Outcomes Between the Study Groups

Outcome Measure	Time Point / Parameter	Group A (Continuous NPWT) Mean \pm SD	Group B (Intermittent NPWT) Mean \pm SD	P value
Wound contraction (%)	6 weeks	68.45 \pm 12.71	76.63 \pm 11.48	0.001
	12 weeks	88.16 \pm 8.15	93.84 \pm 7.61	0.010
Wound closure time (days)	—	82.71 \pm 16.75	72.65 \pm 14.92	0.0001
Length of hospital stay (days)	—	13.75 \pm 4.63	12.81 \pm 3.92	0.160

Table 5 presents a comparison of wound healing outcomes between the continuous and intermittent NPWT groups. Intermittent NPWT demonstrated significantly greater wound contraction at both 6 weeks and 12 weeks compared to continuous NPWT, indicating more rapid and effective reduction in wound size over time. The mean wound closure time was also significantly shorter in the intermittent NPWT group, reflecting faster overall healing. Although the mean duration of hospital stay was slightly lower in patients treated with intermittent NPWT, this difference did not reach statistical significance. Overall, these findings suggest that intermittent NPWT offers superior wound healing efficacy compared to continuous NPWT, particularly in terms of wound contraction and time to closure.

DISCUSSION

The present prospective observational study was conducted at Deccan College of Medical Sciences, Owaisi Hospital & Research Centre to compare the effectiveness of intermittent versus continuous negative pressure wound therapy (NPWT) in the management of diabetic foot ulcers (DFUs). Delayed wound healing is a major clinical challenge, particularly in elderly patients with diabetes, often necessitating prolonged treatment and frequent hospital visits. Conventional wound care methods may require several months for ulcer resolution, prompting the adoption of advanced modalities such as vacuum-assisted closure (VAC) or NPWT to optimize wound healing conditions and reduce dressing frequency and patient discomfort (10).

Although NPWT is relatively expensive and not universally recommended as a first-line therapy, evidence suggests that its judicious use in appropriate patients and wounds can improve outcomes and potentially reduce overall healthcare costs (11). NPWT has been shown to be particularly effective in chronic and complex wounds, producing greater reductions in wound volume and depth, shortening treatment duration, and improving patient satisfaction and quality of life (12). It is generally well tolerated, with few contraindications, and is increasingly regarded as a cornerstone of modern wound care (13).

NPWT facilitates wound healing through multiple mechanisms, including removal of excess exudate and edema, isolation of the wound from external contamination, improvement in local perfusion, and stimulation of angiogenesis and granulation tissue formation (14). Mechanical microdeformation of the wound bed under negative pressure induces cellular proliferation, cytoskeletal reorganization, and extracellular matrix remodeling, thereby accelerating tissue repair (15). Experimental and clinical studies have demonstrated upregulation of angiogenic growth factors such as vascular endothelial growth factor (VEGF) and fibroblast growth factor-2 (FGF-2), along with downregulation of pro-inflammatory cytokines during NPWT (16). These effects are further enhanced by adequate surgical debridement, which reduces bacterial load, limits persistent inflammation, and promotes progression through the normal phases of wound healing (17).

In the present study, both groups were comparable at baseline with respect to age, sex distribution, Wagner grading, comorbidities, ambulatory status, and wound characteristics, thereby minimizing confounding variables. Most patients were aged between 51 and 70 years, consistent with epidemiological studies reporting a higher prevalence of DFUs in older adults (18). Male predominance observed in both groups aligns with previous reports, which attribute this trend to greater occupational exposure, higher prevalence of peripheral arterial disease, and delayed healthcare-seeking

behavior among men (19). The balanced distribution of Wagner grades and comorbid conditions further strengthens the internal validity of the comparative analysis, as ulcer severity and systemic disease burden are known predictors of healing outcomes (20).

With respect to healing outcomes, intermittent NPWT demonstrated superior performance compared with continuous NPWT. A higher proportion of ulcers healed at both 6 weeks and 12 weeks in the intermittent NPWT group, indicating faster and more effective wound resolution. Notably, wound contraction was significantly greater in the intermittent group at both time points, suggesting enhanced wound edge approximation and tissue remodeling. These findings are consistent with previous studies reporting that cyclic application of negative pressure improves tissue perfusion and cellular proliferation more effectively than continuous suction (21). Furthermore, the mean wound closure time was significantly shorter in the intermittent NPWT group, underscoring its advantage in accelerating healing kinetics. Similar observations have been reported by Armstrong et al. and Sandeep et al., who demonstrated increased granulation tissue formation and faster wound closure with NPWT, particularly with intermittent pressure cycles (22).

Although the duration of hospital stay was slightly shorter in the intermittent NPWT group, the difference was not statistically significant. This may be explained by the influence of multiple non-wound-related factors such as glycemic control, comorbid conditions, surgical scheduling, and institutional discharge policies. Comparable findings have been reported in earlier studies, indicating that NPWT modality alone may not independently determine length of hospitalization (23).

Overall, the findings of this study suggest that intermittent NPWT offers measurable advantages over continuous NPWT in terms of wound contraction and time to closure, with a favorable trend toward higher healing rates. These results support the growing body of evidence advocating intermittent NPWT as a more physiologically effective modality for DFU management. Nevertheless, larger randomized controlled trials are required to confirm these findings and to further evaluate long-term outcomes, recurrence rates, patient-reported quality of life, and cost-effectiveness.

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