Int. J Med. Pharm. Res. (P-ISSN: 2958-3675 | E-ISSN: 2958-3683)
Available on: https://ijmpr.in/

International Journal
of Medical and Pharmaceutical Research

ORGINAL ARTICLE **OPEN ACCESS**

A Comparative Study between Silver Based Dressing and Vacuum Dressing in Management of Diabetic Foot Infection

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Received: 15-11-2024
Accepted: 18-12-2024
Available online: 27-12-2024

A B S T R A C T

Background: Diabetic foot infections represent a significant healthcare challenge with considerable morbidity and economic burden. This study aimed to compare the efficacy of silver-based dressings and vacuum dressings in the management of diabetic foot infections.

Methods: This prospective, randomized, comparative study enrolled 96 patients with diabetic foot infections (Wagner grade 2-3) who were randomized to receive either silver-based dressings (n=48) or vacuum dressings (n=48). The primary outcome was time to complete wound healing, with secondary outcomes including infection clearance, percentage reduction in wound area, time to granulation, pain scores, complications.

Results: Complete wound healing at 12 weeks was achieved in 64.6% of the silver-based dressing group versus 81.3% of the vacuum dressing group (p=0.042). The median time to complete healing was significantly shorter with vacuum dressings (51.2 days vs. 68.5 days, p=0.008). The vacuum dressing group demonstrated superior outcomes in percentage reduction in wound area at 4 weeks (57.8% vs. 43.2%, p=0.001), 8 weeks (79.4% vs. 67.9%, p=0.003), and 12 weeks (92.7% vs. 81.5%, p=0.005), faster granulation tissue formation (17.6 vs. 24.3 days, p=0.007), and earlier infection clearance (12.7 vs. 15.2 days, p=0.042). The vacuum dressing group reported lower pain scores after week 1 ($p<0.05$) and higher satisfaction scores (p=0.014).

Conclusion: Vacuum dressings demonstrated superior efficacy compared to silver-based dressings in the management of diabetic foot infections across multiple parameters including healing time, infection clearance, and patient comfort. These findings support the preferential use of vacuum dressings in the management of diabetic foot infections, particularly in moderate to severe cases.

Keywords: Diabetic foot infection; Silver dressing; Vacuum dressing; Negative pressure wound therapy; Wound healing.

INTRODUCTION

Diabetic foot infection represents one of the most challenging complications of diabetes mellitus, often leading to significant morbidity, decreased quality of life, and substantial healthcare costs. Globally, the prevalence of diabetic foot ulcers ranges from 6.3% to 10.5%, with infection complicating approximately 50% of these ulcers[1]. Diabetic foot infections account for more hospitalizations than any other diabetes-related complication and remain the leading cause of non-traumatic lower limb amputations worldwide[2]. The economic burden is equally substantial, with annual direct costs estimated at $9-13 billion in the United States alone, beyond the associated costs of disability, productivity loss, and premature mortality[3].

The pathophysiology of diabetic foot infections is multifactorial, characterized by a complex interplay of peripheral neuropathy, peripheral arterial disease, immunological dysfunction, and altered biomechanics[4]. Neuropathy diminishes protective sensation, leading to unrecognized trauma and pressure points, while impaired blood supply compromises tissue oxygenation and healing capacity. Hyperglycemia further impairs neutrophil function, chemotaxis, and phagocytosis, creating an environment conducive to infection. These infections typically present as polymicrobial, with

both aerobic and anaerobic organisms, commonly including Staphylococcus aureus, Streptococcus species, Enterobacteriaceae, Pseudomonas aeruginosa, and various anaerobes[2].

Management of diabetic foot infections requires a multidisciplinary approach encompassing glycemic control, offloading, vascular assessment, antibiotic therapy, and appropriate wound care[5]. While systemic antibiotics address the underlying infection, local wound management plays a crucial role in creating an optimal environment for healing. Traditional wound dressings have evolved significantly over the past decades, with modern advanced wound care products designed to address specific aspects of wound physiology[6].

Silver-based dressings have emerged as a prominent option in the management of infected diabetic foot ulcers. Silver ions possess broad-spectrum antimicrobial properties against gram-positive and gram-negative bacteria, including antibiotic-resistant strains, fungi, and certain viruses. The mechanism involves binding to bacterial cell membranes, penetrating cell walls, and disrupting cellular processes including respiration, replication, and protein synthesis[7]. Contemporary silver dressings utilize various delivery systems, including silver sulfadiazine, nanocrystalline silver, and silver-impregnated activated charcoal, each offering distinct release kinetics and longevity of antimicrobial action[6]. Several clinical studies have demonstrated the efficacy of silver-based dressings in reducing bacterial burden, controlling local infection, and promoting healing in diabetic foot ulcers[8].

Concurrently, negative pressure wound therapy (NPWT), also known as vacuum-assisted closure or vacuum dressing, has revolutionized the management of complex wounds, including diabetic foot infections. This modality employs controlled subatmospheric pressure applied uniformly to the wound bed through specialized foam or gauze dressings sealed with an adhesive drape and connected to a vacuum pump[9]. The mechanism of action is multifaceted, including macrodeformation (wound contraction), microdeformation (cellular strain), fluid removal, and environmental control. These effects collectively stimulate granulation tissue formation, reduce edema, improve perfusion, and decrease bacterial colonization[9]. Multiple randomized controlled trials have reported accelerated wound healing, reduced time to wound closure, and decreased amputation rates with NPWT compared to conventional dressings in diabetic foot wounds[10].

Despite the established benefits of both silver-based dressings and NPWT in diabetic foot infections, comparative studies directly evaluating their relative efficacy, safety, and effectiveness remain limited. The optimal choice between these modalities in various clinical scenarios, wound characteristics, and patient populations remains unclear. Furthermore, concerns regarding silver toxicity to keratinocytes and fibroblasts at certain concentrations, as well as the potential development of bacterial resistance with prolonged use, warrant careful consideration[7]. Similarly, NPWT has limitations including contraindication in malignant wounds, untreated osteomyelitis, and exposed vital structures, along with potential complications such as pain, bleeding, and skin maceration[9].

Therefore, this study aims to conduct a comparative analysis of silver-based dressings and vacuum dressings in the management of diabetic foot infections, evaluating parameters including rate of infection clearance, time to wound healing, reduction in wound dimensions, granulation tissue formation, patient comfort. By elucidating the relative advantages and limitations of each modality across various clinical parameters, this research endeavors to provide evidence-based guidance for clinicians in selecting the optimal wound care approach for patients with diabetic foot infections, potentially improving healing outcomes and reducing the risk of amputations.

AIMS AND OBJECTIVES

The primary aim of this study was to compare the efficacy of silver-based dressings and vacuum dressings in the management of diabetic foot infections. The specific objectives were to evaluate and compare the two modalities with respect to rate of infection clearance, time to wound healing, reduction in wound dimensions, granulation tissue formation, pain scores, patient comfort, and incidence of complications including amputation. The study also sought to identify patient and wound characteristics that might predict better outcomes with either modality, thereby facilitating personalized treatment selection in clinical practice.

MATERIALS AND METHODS

Study Design and Setting

This prospective, randomized, comparative study was conducted at the Department of Surgery in collaboration with the Department of Endocrinology at a tertiary care teaching hospital between January 2023 and December 2023. The study protocol was approved by the Institutional Ethics Committee (IEC/2022/1245) and registered with the Clinical Trials Registry (CTRI/2022/12/046792). Written informed consent was obtained from all participants prior to enrollment.

Study Population

Patients aged 18 years and above with type 1 or type 2 diabetes mellitus who presented with infected foot ulcers (Wagner grade 2 or 3) were screened for eligibility. Infection was diagnosed based on clinical criteria as per the Infectious Diseases Society of America (IDSA) guidelines, including the presence of purulence, erythema, local warmth, tenderness, induration, and/or malodor. A total of 126 patients met the initial screening criteria.

The inclusion criteria encompassed diabetic patients with infected foot ulcers of size 5-15 cm^2 and a history of ulcer duration not exceeding three months. Exclusion criteria were applied to eliminate confounding factors and ensure safety. Patients with uncontrolled diabetes (HbA1c > 10%), critical limb ischemia (ankle-brachial index < 0.5 or absence of pedal pulses requiring revascularization), osteomyelitis confirmed by radiological investigations, exposed tendons or bones, malignant wounds, bleeding disorders, known hypersensitivity to silver, or those on immunosuppressive therapy were excluded. Additionally, pregnant or lactating women and patients who had received systemic antibiotics for more than 48 hours prior to enrollment were not included. After applying these criteria, 96 patients were deemed eligible and enrolled in the study.

Randomization and Allocation

The enrolled patients were randomized into two equal groups of 48 patients each using computer-generated random number tables. Group A received silver-based dressings, while Group B received vacuum dressings. The allocation was concealed using sequentially numbered, opaque, sealed envelopes that were opened only after patient enrollment. Due to the nature of the interventions, blinding of the treating clinicians and patients was not feasible; however, the assessors evaluating wound healing parameters and microbiological analyses were blinded to the treatment allocation.

Pre-intervention Assessment

A comprehensive baseline assessment was conducted for all enrolled patients. Demographic data including age, gender, body mass index, occupation, and socioeconomic status were recorded. Detailed medical history encompassed the type and duration of diabetes, presence of comorbidities, history of previous foot ulcers or amputations, and current medications. Laboratory investigations included complete blood count, renal function tests, liver function tests, fasting and postprandial blood glucose levels, HbA1c, lipid profile, and serum albumin.

Wound assessment was performed meticulously, documenting the location, size, depth, and characteristics of the ulcer. Wound dimensions were measured using sterile transparent grid sheets and digital planimetry. The presence of necrotic tissue, slough, granulation tissue, and wound exudate was noted. Tissue samples were obtained for microbiological culture and sensitivity testing using deep tissue biopsy or curettage techniques after wound debridement to avoid surface contamination. Radiological investigations including plain radiographs and magnetic resonance imaging were performed when clinically indicated to exclude osteomyelitis.

Vascular assessment included palpation of peripheral pulses, ankle-brachial index measurement, and duplex ultrasonography when indicated. Neurological examination comprised evaluation of protective sensation using Semmes-Weinstein 10g monofilament and vibration perception using a 128 Hz tuning fork.

Intervention Protocol

All patients underwent initial surgical debridement under appropriate anesthesia to remove necrotic tissue, slough, and foreign material until healthy, bleeding tissue was encountered. Wound cultures were obtained post-debridement. Empirical broad-spectrum antibiotics were initiated based on institutional protocols and subsequently modified according to culture sensitivity reports.

In Group A, silver-based dressings (nanocrystalline silver-containing foam dressings) were applied directly to the wound bed after gentle cleansing with normal saline. The dressings were secured with secondary dressings and bandages. Dressing changes were performed every 48-72 hours depending on the amount of exudate, or earlier if strikethrough was observed. The frequency was adjusted based on wound characteristics and clinical response.

In Group B, vacuum dressing was applied using a specialized vacuum-assisted closure device. After wound cleansing, a polyurethane foam dressing was trimmed to match the wound dimensions and placed within the wound cavity. The foam was covered with an adhesive drape creating an airtight seal, and a suction tube was connected to a vacuum pump. Continuous negative pressure was applied at -125 mmHg for the first 48 hours, followed by intermittent negative pressure (5 minutes on, 2 minutes off) at the same pressure level. The vacuum dressing was changed every 72-96 hours.

Both groups received standard diabetic care including glycemic control, offloading using appropriate footwear or total contact casting, nutritional support, and management of comorbidities. Patients were advised to restrict ambulation, with non-weight bearing status maintained for plantar ulcers.

Outcome Assessment

Follow-up evaluations were conducted weekly for a period of 12 weeks or until complete wound healing, whichever occurred earlier. At each visit, detailed wound assessment was performed documenting changes in wound dimensions, presence of infection, quality of granulation tissue, and epithelialization. Wound surface area was calculated using digital planimetry. The rate of wound contraction was expressed as percentage reduction in wound area from baseline.

Microbiological cultures were repeated weekly for the first four weeks and thereafter if clinically indicated to assess clearance of infection. Pain was evaluated using a visual analog scale (0-10) at each dressing change. Patient comfort and

satisfaction were assessed using a modified Likert scale questionnaire addressing pain during dressing changes, odor control, leakage, interference with daily activities, and overall satisfaction.
Adverse events including periwound maceration, dermatitis, bleeding, and worsening infection were documented. Major outcomes including need for additional debridement, higher amputation, or discontinuation of assigned treatment were recorded.
The primary endpoint was time to complete wound healing, defined as 100% epithelialization without drainage. Secondary endpoints included rate of infection clearance (negative cultures), percentage reduction in wound area at 4, 8, and 12 weeks, time to achieve healthy granulation tissue covering >90% of the wound bed, pain scores, incidence of complications.

Statistical Analysis
Data were analyzed using Statistical Package for Social Sciences (SPSS) version 25.0. Continuous variables were expressed as mean ± standard deviation or median with interquartile range depending on the distribution. Categorical variables were presented as frequencies and percentages. Normality of data distribution was assessed using the Shapiro-Wilk test.
Intergroup comparisons for continuous variables were performed using independent t-test for normally distributed data and Mann-Whitney U test for non-parametric data. Categorical variables were compared using Chi-square test or Fisher's exact test as appropriate. For time-to-event analyses including time to complete healing and infection clearance, Kaplan-Meier survival curves were constructed and compared using log-rank test.
Repeated measures analysis of variance (ANOVA) was employed to analyze changes in wound area, pain scores, and other parameters measured over time. Multiple logistic regression analysis was performed to identify factors independently associated with successful wound healing. A p-value <0.05 was considered statistically significant for all analyses.

RESULTS
A total of 96 patients with diabetic foot infections were randomized into two equal groups: the silver-based dressing group (n=48) and the vacuum dressing group (n=48). The baseline demographic and clinical characteristics were comparable between the two groups, with no statistically significant differences observed in age, gender distribution, body mass index, duration of diabetes, glycemic control, wound characteristics, or comorbidities (Table 1). The mean age of participants was 58.4 ± 9.7 years in the silver-based dressing group and 56.8 ± 10.3 years in the vacuum dressing group (p=0.432). Males predominated in both groups, constituting 66.7% and 62.5% of the silver-based dressing and vacuum dressing groups, respectively (p=0.683). The mean duration of diabetes was comparable between the two groups (11.5 vs. 12.3 years, p=0.512), as was the mean HbA1c level (8.2% vs. 8.4%, p=0.427).
The microbiological profile of diabetic foot infections at baseline demonstrated polymicrobial growth in 64.6% of patients in the silver-based dressing group and 60.4% in the vacuum dressing group (p=0.675), with no significant between-group differences in the distribution of specific pathogens (Table 2). Staphylococcus aureus was the most commonly isolated organism in both groups (58.3% vs. 54.2%, p=0.683), followed by Pseudomonas aeruginosa (39.6% vs. 43.8%, p=0.683). Methicillin-resistant Staphylococcus aureus (MRSA) was identified in 22.9% and 18.8% of patients in the silver-based dressing and vacuum dressing groups, respectively (p=0.624).
Complete wound healing at 12 weeks was achieved in 31 patients (64.6%) in the silver-based dressing group compared to 39 patients (81.3%) in the vacuum dressing group, representing a statistically significant difference (p=0.042). The median time to complete wound healing was significantly shorter in the vacuum dressing group (51.2 days, IQR 42-64 days) compared to the silver-based dressing group (68.5 days, IQR 54-82 days) (p=0.008) (Table 3). Kaplan-Meier survival analysis confirmed this finding, with the log-rank test demonstrating a significant difference between the two groups (p=0.007).
The percentage reduction in wound area was consistently greater in the vacuum dressing group across all time points. At 4 weeks, the mean percentage reduction was 57.8 ± 13.2% in the vacuum dressing group compared to 43.2 ± 11.6% in the silver-based dressing group (p=0.001). This trend persisted at 8 weeks (79.4 ± 14.1% vs. 67.9 ± 15.3%, p=0.003) and 12 weeks (92.7 ± 12.3% vs. 81.5 ± 17.2%, p=0.005). The mean rate of wound healing, expressed as reduction in wound area per week, was significantly higher in the vacuum dressing group (0.91 ± 0.29 cm^2/week) compared to the silver-based dressing group (0.73 ± 0.25 cm^2/week) (p=0.002).
The vacuum dressing group demonstrated more rapid development of healthy granulation tissue, with a median time of 17.6 days (IQR 13-23 days) compared to 24.3 days (IQR 18-31 days) in the silver-based dressing group (p=0.007). Similarly, the median time to infection clearance, as evidenced by negative wound cultures, was significantly shorter in the vacuum dressing group (12.7 days, IQR 8-17 days) compared to the silver-based dressing group (15.2 days, IQR 10-21 days) (p=0.042).
The need for additional surgical debridement was observed in 14 patients (29.2%) in the silver-based dressing group compared to 9 patients (18.8%) in the vacuum dressing group, although this difference did not reach statistical

significance (p=0.231). The incidence of minor amputations (toe or partial foot) was 10.4% in the silver-based dressing group and 6.3% in the vacuum dressing group (p=0.715), while major amputations (above or below knee) occurred in 2 patients (4.2%) in the silver-based dressing group and 1 patient (2.1%) in the vacuum dressing group (p=1.000).

Pain assessment using the visual analog scale revealed comparable scores between the two groups during the first week of treatment (6.3 ± 1.8 vs. 5.7 ± 1.9, p=0.112). However, from the second week onwards, patients in the vacuum dressing group reported significantly lower pain scores during dressing changes compared to those in the silver-based dressing group (Table 4). By week 4, the mean pain score was 1.8 ± 1.2 in the vacuum dressing group compared to 2.6 ± 1.3 in the silver-based dressing group (p=0.002). Patient satisfaction scores were significantly higher in the vacuum dressing group (median 4.2, IQR 3-5) compared to the silver-based dressing group (median 3.7, IQR 3-4) (p=0.014).

The profile of adverse events differed between the two groups, although individual comparisons did not reach statistical significance. Periwound maceration (27.1% vs. 16.7%, p=0.217) and contact dermatitis (14.6% vs. 4.2%, p=0.159) were more common in the silver-based dressing group, while bleeding during dressing changes occurred more frequently in the vacuum dressing group (18.8% vs. 10.4%, p=0.247). Pressure necrosis was observed exclusively in the vacuum dressing group, affecting 3 patients (6.3%). Treatment discontinuation due to adverse events or patient preference occurred in 3 patients (6.3%) in the silver-based dressing group and 2 patients (4.2%) in the vacuum dressing group (p=1.000).

Table 1: Baseline Demographic and Clinical Characteristics of Study Participants

Characteristic	Silver-Based Dressing (n=48)	Vacuum Dressing (n=48)	p-value
Age (years), mean ± SD	58.4 ± 9.7	56.8 ± 10.3	0.432
Gender, n (%)			0.683
Male	32 (66.7)	30 (62.5)	
Female	16 (33.3)	18 (37.5)	
BMI (kg/m²), mean ± SD	27.3 ± 4.1	28.1 ± 3.9	0.324
Duration of diabetes (years), median (IQR)	11.5 (7.3-15.8)	12.3 (8.1-16.2)	0.512
HbA1c (%), mean ± SD	8.2 ± 1.3	8.4 ± 1.2	0.427
Wagner Grade, n (%)			0.839
Grade 2	31 (64.6)	32 (66.7)	
Grade 3	17 (35.4)	16 (33.3)	
Ulcer location, n (%)			0.945
Forefoot	29 (60.4)	28 (58.3)	
Midfoot	13 (27.1)	14 (29.2)	
Hindfoot	6 (12.5)	6 (12.5)	
Ulcer duration (weeks), median (IQR)	4.2 (2.8-6.5)	4.5 (3.0-7.1)	0.583
Ulcer size (cm²), mean ± SD	9.7 ± 2.9	9.4 ± 3.1	0.614
Peripheral neuropathy, n (%)	42 (87.5)	40 (83.3)	0.567
Ankle-Brachial Index, mean ± SD	0.84 ± 0.12	0.86 ± 0.11	0.392
Serum albumin (g/dL), mean ± SD	3.3 ± 0.5	3.4 ± 0.4	0.276

Table 2: Microbiological Profile of Diabetic Foot Infections at Baseline

Microorganism	Silver-Based Dressing (n=48)	Vacuum Dressing (n=48)	p-value
Monomicrobial infections, n (%)	17 (35.4)	19 (39.6)	0.675
Polymicrobial infections, n (%)	31 (64.6)	29 (60.4)	0.675
Isolates, n (%)			
Staphylococcus aureus	28 (58.3)	26 (54.2)	0.683
MRSA	11 (22.9)	9 (18.8)	0.624
Streptococcus species	15 (31.3)	17 (35.4)	0.667

Microorganism	Silver-Based Dressing (n=48)	Vacuum Dressing (n=48)	p-value
Enterococcus species	9 (18.8)	11 (22.9)	0.624
Escherichia coli	16 (33.3)	14 (29.2)	0.663
Klebsiella species	12 (25.0)	10 (20.8)	0.629
Proteus species	8 (16.7)	9 (18.8)	0.789
Pseudomonas aeruginosa	19 (39.6)	21 (43.8)	0.683
Bacteroides species	7 (14.6)	6 (12.5)	0.766
Other anaerobes	10 (20.8)	12 (25.0)	0.629

Table 3: Comparison of Wound Healing Outcomes Between Silver-Based Dressing and Vacuum Dressing Groups

Outcome	Silver-Based Dressing (n=48)	Vacuum Dressing (n=48)	p-value
Complete wound healing at 12 weeks, n (%)	31 (64.6)	39 (81.3)	0.042*
Time to complete healing (days), median (IQR)	68.5 (54-82)	51.2 (42-64)	0.008*
Percentage reduction in wound area, mean ± SD			
At 4 weeks	43.2 ± 11.6	57.8 ± 13.2	0.001*
At 8 weeks	67.9 ± 15.3	79.4 ± 14.1	0.003*
At 12 weeks	81.5 ± 17.2	92.7 ± 12.3	0.005*
Rate of wound healing (cm^2/week), mean ± SD	0.73 ± 0.25	0.91 ± 0.29	0.002*
Time to healthy granulation tissue (days), median (IQR)	24.3 (18-31)	17.6 (13-23)	0.007*
Time to infection clearance (days), median (IQR)	15.2 (10-21)	12.7 (8-17)	0.042*
Wounds requiring additional debridement, n (%)	14 (29.2)	9 (18.8)	0.231
Minor amputation, n (%)	5 (10.4)	3 (6.3)	0.715
Major amputation, n (%)	2 (4.2)	1 (2.1)	1.000

*Statistically significant ($p<0.05$)

Table 4: Comparison of Pain Scores, Patient Comfort, and Adverse Events Between Groups

Parameter	Silver-Based Dressing (n=48)	Vacuum Dressing (n=48)	p-value
Pain score during dressing change (VAS 0-10), mean ± SD			
Week 1	6.3 ± 1.8	5.7 ± 1.9	0.112
Week 2	5.1 ± 1.6	4.2 ± 1.7	0.009*
Week 3	3.8 ± 1.5	2.9 ± 1.4	0.003*
Week 4	2.6 ± 1.3	1.8 ± 1.2	0.002*
Patient satisfaction score (1-5), median (IQR)	3.7 (3-4)	4.2 (3-5)	0.014*
Adverse events, n (%)			
Periwound maceration	13 (27.1)	8 (16.7)	0.217
Contact dermatitis	7 (14.6)	2 (4.2)	0.159
Bleeding during dressing change	5 (10.4)	9 (18.8)	0.247
Wound infection recurrence	8 (16.7)	4 (8.3)	0.218
Pressure necrosis	0 (0.0)	3 (6.3)	0.242
Treatment discontinuation	3 (6.3)	2 (4.2)	1.000

*Statistically significant ($p<0.05$)

DISCUSSION

This prospective, randomized study compared the efficacy of silver-based dressings and vacuum dressings in the management of diabetic foot infections, demonstrating superior outcomes with vacuum dressings across multiple parameters including time to wound healing, reduction in wound area, granulation tissue formation, infection clearance, patient comfort. These findings provide valuable insights to inform clinical decision-making in the management of this challenging complication of diabetes.

The significantly higher rate of complete wound healing at 12 weeks observed with vacuum dressings (81.3% vs. 64.6%, p=0.042) aligns with findings from previous studies. Blume et al. reported a 43.2% complete closure rate with NPWT compared to 28.9% with advanced moist wound therapy in diabetic foot ulcers at 16 weeks (p=0.007)[11]. Similarly, Armstrong et al. demonstrated a 56% closure rate with NPWT versus 39% with moist wound therapy in partial diabetic foot amputations (p=0.040)[12]. The median time to complete healing in our study was 51.2 days with vacuum dressings compared to 68.5 days with silver-based dressings (p=0.008), representing a 25.3% reduction. This acceleration of wound healing is consistent with the findings of Sepúlveda et al., who reported a 40% reduction in healing time with NPWT compared to conventional dressings in diabetic foot ulcers (p<0.001)[13].

The superior efficacy of vacuum dressings in promoting wound contraction, as evidenced by the significantly greater percentage reduction in wound area at all time points, can be attributed to multiple mechanisms. NPWT exerts macrodeformation forces that physically contract the wound, microdeformation at the cellular level that stimulates proliferation and migration of wound edge cells, and removal of exudate that might contain matrix metalloproteinases and other factors inhibiting healing[14]. In contrast, while silver-based dressings effectively address the infectious component through antimicrobial action, they do not actively promote wound contraction. Yao et al. reported a 59.2% reduction in wound area with NPWT at 4 weeks compared to 37.5% with conventional dressings (p<0.01) in diabetic foot ulcers, similar to our findings of 57.8% versus 43.2% (p=0.001)[15].

The more rapid development of healthy granulation tissue with vacuum dressings (17.6 vs. 24.3 days, p=0.007) observed in our study supports the known pro-angiogenic effects of NPWT. Negative pressure has been shown to increase capillary density, blood flow, and tissue oxygenation while promoting fibroblast migration and extracellular matrix deposition[16]. Xie et al. demonstrated a 63.3% increase in capillary formation with NPWT compared to conventional dressings (p<0.001)[17]. Furthermore, the mechanical stress induced by NPWT upregulates vascular endothelial growth factor (VEGF) and fibroblast growth factor-2 (FGF-2), promoting angiogenesis and granulation tissue formation[18].

The faster infection clearance observed with vacuum dressings (12.7 vs. 15.2 days, p=0.042) might seem counterintuitive given the known antimicrobial properties of silver. However, NPWT effectively removes wound exudate containing bacteria and toxins, reduces edema improving tissue perfusion and antibiotic delivery, and creates a sealed environment preventing external contamination[19]. Moues et al. reported a significant reduction in bacterial load with NPWT compared to conventional dressings (p<0.001), particularly for non-fermentative gram-negative bacilli[20]. In contrast, while silver ions effectively kill bacteria in vitro, their in vivo efficacy may be limited by binding to proteins and chloride ions in wound exudate, reducing bioavailability[21].

The lower pain scores during dressing changes observed with vacuum dressings after the first week (p<0.05) contradicts the common perception that NPWT is more painful. This finding may be attributed to less frequent dressing changes with NPWT (every 72-96 hours vs. every 48-72 hours), reduced wound manipulation during changes, and decreased exposure of nerve endings as granulation tissue forms more rapidly. Nain et al. similarly reported lower pain scores with NPWT compared to conventional dressings in diabetic foot ulcers (p<0.05)[22]. The higher patient satisfaction scores with vacuum dressings (p=0.014) likely reflect the combination of faster healing, less frequent dressing changes, better odor control, and reduced pain.

The pattern of adverse events observed in our study reflects the known safety profiles of the two modalities. The higher incidence of periwound maceration (27.1% vs. 16.7%) and contact dermatitis (14.6% vs. 4.2%) with silver-based dressings has been reported previously, with rates of skin irritation ranging from 3% to 25% in various studies[23]. These effects are attributed to the cytotoxic properties of silver ions and accumulation of exudate. Conversely, bleeding during dressing changes was more common with vacuum dressings (18.8% vs. 10.4%), likely due to disruption of newly formed capillaries in granulation tissue when foam adheres to the wound bed. Pressure necrosis, observed exclusively in the vacuum dressing group (6.3%), typically occurs when pressure is unevenly distributed or tubing compresses tissues[24].

The amputation rates in our study, while not statistically different between groups, showed a trend favoring vacuum dressings for both minor (6.3% vs. 10.4%) and major amputations (2.1% vs. 4.2%). This aligns with findings from a meta-analysis by Liu et al., which demonstrated a significant reduction in amputation risk with NPWT compared to conventional dressings in diabetic foot ulcers (relative risk 0.31, 95% CI 0.15-0.62, p<0.001)[25]. The mechanisms likely involve more rapid infection control, better preservation of viable tissue during debridement due to clearer tissue planes, and accelerated wound healing.

Several limitations of our study warrant consideration. The follow-up period of 12 weeks may not have captured long-term outcomes including ulcer recurrence. Blinding was not feasible due to the nature of the interventions, potentially introducing bias in subjective assessments. The single-center design may limit generalizability, and the sample size, while adequately powered for the primary outcome, may have been insufficient to detect significant differences in less common outcomes such as amputations.

CONCLUSION

This prospective, randomized study demonstrated that vacuum dressings are superior to silver-based dressings in the management of diabetic foot infections across multiple clinically relevant parameters. Vacuum dressings achieved faster wound healing, earlier infection clearance, more rapid granulation tissue formation, greater reduction in wound dimensions, lower pain scores, and higher patient satisfaction. These findings support the preferential use of vacuum dressings in the management of diabetic foot infections, particularly in moderate to severe cases. Future research should investigate the optimal duration of vacuum therapy, potential benefits of combined or sequential therapy with silver-based dressings, and long-term outcomes including recurrence rates and quality of life measures.

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