Original Article

Comparative Study of Vacuum Assisted Closure and 3% Citric Acid Dressing in the Management of Diabetic Foot Ulcers in Resource Limited Settings

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Abstract

Background: Diabetic foot ulcers (DFUs) are a major cause of morbidity, with a significant risk of amputation if not managed effectively. Advanced wound care modalities such as Vacuum Assisted Closure (VAC) therapy and economical alternatives like 3% citric acid dressings have shown promise, but comparative evidence remains limited. **Material and Methods:** This prospective comparative study was conducted at Government General Hospital, Vijayawada, from December 2018 to November 2020.Sixty patients with non-traumatic diabetic foot ulcers were randomly allocated into two groups: VAC therapy (Group A, n=30) and 3% citric acid dressing (Group B, n=30). All patients underwent debridement and standard care. Wound area was measured using photographic analysis with ImageJ software. Primary outcome was percentage reduction in wound area; secondary outcome was duration of hospital stay. **Results:** Baseline characteristics were comparable between groups. The mean percentage reduction in wound area was significantly higher in the VAC group (23.10% ± 4.26) compared to the citric acid group (17.90% ± 3.17) ($p < 0.001$). Mean hospital stay was also significantly shorter in the VAC group (14.3 ± 2.36 days) compared to the citric acid group (19.4 ± 3.97 days) ($p < 0.001$). Staphylococcus species were the most commonly isolated organisms. **Conclusion:** VAC therapy is significantly more effective than 3% citric acid dressing in promoting wound healing and reducing hospital stay in DFUs. However, citric acid remains a cost-effective alternative in resource-limited settings.

Keywords: 3% Citric acid, VAC, Vacuum Assisted Closure, Negative Pressure Wound Therapy, Diabetic foot ulcer, diabetic foot complications.

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Introduction

Diabetic foot ulcers impose a significant clinical and public health burden. It is estimated that approximately 15-25% of individuals with diabetes will develop a foot ulcer during their lifetime.[1-3] While 60-80% of these ulcers heal with appropriate treatment,[4] nearly 10-15% become chronic and non-healing.[5] Importantly, about 5-24% of patients with diabetic foot ulcers may require lower limb amputation within 6-18 months of initial presentation.[6] About 70 to 85% of amputations in diabetic individuals are preceded by a foot ulcer.[7] Globally, it is estimated that a lower limb is lost due to diabetes every 30 seconds (International Diabetes Federation. Time to Act: Diabetes and Foot Care. Brussels: IDF; 2005). However, studies suggest that nearly 80% of diabetes-related amputations are preventable with early detection and appropriate management.[8,9]

Management of diabetic foot ulcers requires a comprehensive multidisciplinary approach that includes strict glycemic control, infection management, surgical debridement, pressure off-loading, and appropriate wound care. Among these, wound dressing plays a critical role in facilitating healing. An ideal wound dressing should maintain a moist environment, reduce bacterial contamination, promote granulation tissue formation, and facilitate epithelialization.

Vacuum Assisted Closure (VAC), also known as Negative Pressure Wound Therapy (NPWT), has emerged as an effective modality for the management of complex and chronic wounds.[10-13] VAC therapy involves the application of controlled negative pressure to the wound using a sealed dressing connected to a vacuum pump. The negative pressure facilitates removal of wound exudates, reduces tissue edema, improves local blood circulation, and stimulates granulation tissue formation. Mechanical stress induced by negative pressure also promotes angiogenesis and cellular proliferation, thereby accelerating wound healing.

Another modality gaining interest in wound care especially in

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resource limited scenarios is the use of citric acid dressings.[14,15] Citric acid is a weak organic acid with antimicrobial properties. When applied to wounds, it lowers the local pH, creating an environment that inhibits bacterial growth and reduces the activity of proteolytic enzymes that impede wound healing. An acidic environment also enhances oxygen release and stimulates fibroblast proliferation, thereby promoting granulation tissue formation. The use of 3% citric acid solution has been proposed as a simple, inexpensive, and effective dressing option, particularly in resource-limited settings.

Although several studies have evaluated these modalities individually, comparative data between VAC therapy and 3% citric acid dressings in diabetic foot ulcers remain limited. The present study was therefore undertaken to compare the efficacy of Vacuum Assisted Closure therapy and 3% citric acid dressings in the management of diabetic foot ulcers, with emphasis on wound healing rate and duration of hospital stay.

Materials and Methods

Aim and Objectives: The aim of this study was to compare the efficacy of Vacuum Assisted Closure therapy and 3% citric acid dressings in the management of diabetic foot ulcers.

The objectives of the study were:

To evaluate the rate of wound healing based on percentage reduction in wound size, to assess the duration of hospital stay, to analyse demographic characteristics of patients, To identify common bacterial pathogens in diabetic foot ulcers and to determine whether there was a statistically significant difference between the two treatment modalities

Study Design and Setting: This was a prospective comparative study conducted on 60 patients with diabetic foot ulcers, with 30 patients in each group conducted at Government General Hospital, Vijayawada, from December 2018 to November 2020 after obtaining informed written consent. The sample size was determined based on feasibility and patient availability during the study period. Ethical clearance was obtained from the Institutional Ethics Committee before initiation of the study. Eligible patients were randomly divided into two groups consisting of 30 patients each:

Group A - Vacuum Assisted Closure (VAC) therapy Group B - 3% Citric Acid dressing

The primary outcome measure was percentage reduction in wound size. With this sample size, the study was adequately powered to detect a difference between the two groups at a significance level (α) of 0.05.

The study endpoint for each patient was the development of healthy granulation tissue over the wound, making it suitable for definitive management such as skin grafting or healing by secondary intention.

Inclusion Criteria

Patients aged between 20 and 70 years, Patients with non-traumatic diabetic foot ulcers and Patients providing informed consent

Exclusion Criteria

Patients were excluded if they had - Traumatic wounds, Chronic osteomyelitis, Chronic non-healing ulcers unrelated to diabetes, Pressure sores, Unexplored fistulae, Ulcers suspicious of malignancy, Severe anemia (Hb< 8g/dL), Hypoalbuminemia, Major systemic illness, Exposed major blood vessels, Charcot's foot, Collagen vascular diseases, Patients receiving chemotherapy, immunosuppressive drugs, or corticosteroids. These conditions were excluded as they could significantly influence wound healing and act as confounding variables.

Initial Assessment and Management: All patients underwent detailed clinical evaluation and relevant laboratory investigations at the time of admission. Wound swabs were collected for culture and sensitivity testing. Empirical broad-spectrum antibiotics were initiated and later modified based on culture reports.

All wounds underwent thorough surgical debridement to remove necrotic tissue, slough, and debris. This step was essential to prepare the wound bed for optimal healing.

Following debridement, a standardized digital photograph of the wound was taken with a 4 × 4 cm² graph paper placed adjacent to the wound. This image served as the baseline for wound measurement.

Patients were then randomly allocated to either VAC therapy or 3% citric acid dressing. Wound Area Measurement

Wound surface area was measured using a photographic technique described by Rahul Shetty et al.[16] A standardized digital photograph was taken with graph paper placed beside the wound as a reference scale [Figure 1].

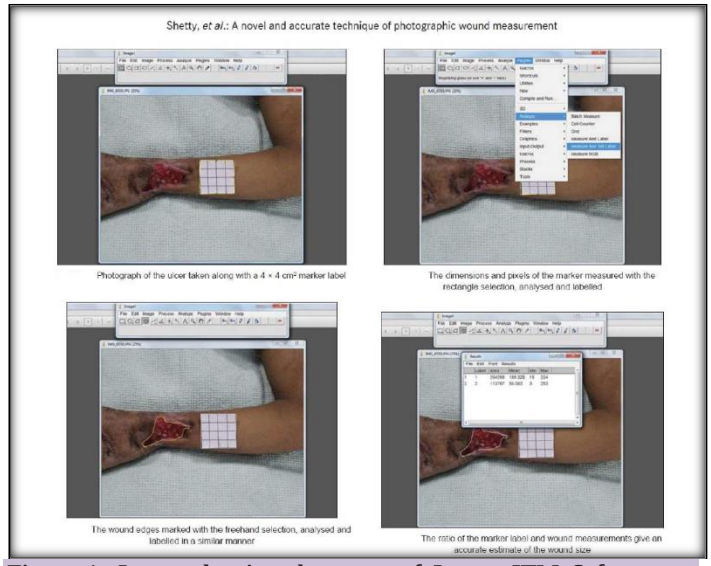

Figure 1: Image showing the usage of Image JTM Software to Calculate the wound surface area by pixels in the wound area

The wound area was calculated using ImageJ™ open-source software, which determines the area in pixels. The known graph paper area was also measured in pixels, allowing calculation of wound area using pixel ratio conversion.

If 1 cm² of graph paper corresponded to x pixels and the wound area corresponded to y pixels, the wound area was calculated as:

Wound area (cm²) = y/x

The initial wound area was designated A1, while the final

wound area at the study endpoint was designated A2.

Treatment Protocol

Group A - Vacuum Assisted Closure (VAC)

Patients in Group A were treated using Negative Pressure Wound Therapy. After debridement, a polyurethane foam dressing was cut to match the wound size and placed over the wound bed. The dressing was then sealed using a transparent adhesive drape to create an airtight environment. (Figure 2).

Figure 2: Image showing the technique employed and the apparatus used to perform VAC dressing

A suction tube was inserted into the foam dressing and connected to a suction system with a pressure control valve. Controlled negative pressure was applied to remove exudates, reduce oedema, and promote granulation tissue formation.

Dressing changes were performed at regular intervals depending on the amount of wound exudates and clinical assessment.

Group B - 3% Citric Acid Dressing

Patients in Group B were treated with gauze soaked in 3% citric acid solution. After wound cleaning and debridement, the citric acid-soaked gauze was placed directly over the wound surface and covered with sterile dressing pads and a roller bandage. (Figure 3).

Figure 3: Image showing 3% Citric acid from commercially available citric acid crystals

Dressings were changed two to three times per week depending on wound condition and soakage.

Outcome Measures Primary Outcome

Percentage reduction in wound surface area: This was calculated using the formula:

Percentage wound healing (%) = (A1 − A2) / A1 × 100

Secondary Outcome

Duration of hospital stay, defined as the number of days from admission until adequate granulation tissue formation.

Statistical Analysis

Data were analysed using Shapiro wilk tests and Independent t tests on SPSS software. The distribution of percentage wound healing and duration of hospital stay in both groups was assessed, which confirmed normal distribution.

A p-value of less than 0.05 was considered statistically significant.

Results

A total of 60 patients with diabetic foot ulcers were included in the study and equally divided into two groups.

Group A - VAC therapy (30 patients)

Group B - 3% Citric Acid dressing (30 patients)

Statistical tests confirmed normal distribution of the outcome variables in both groups.

Demographic Characteristics Age Distribution

The mean age of patients in the study was 54.9 years, ranging from 41 to 70 years.

Gender Distribution

The study demonstrated a clear male predominance with a male-to-female ratio of approximately 3:1.

Duration of Diabetes

The overall mean duration of diabetes among the study participants was 9.49 years.

Wound Culture Findings

Wound culture at admission was positive in 78.34% of patients, while 21.66% showed no bacterial growth.

The most commonly isolated organisms were:

- Staphylococcus species - 36.6%
- Escherichia coli - 18.3%
- Klebsiella species - 13.3%
- Pseudomonas species - 10%

Most patients presented with infected wounds containing necrotic tissue and debris. [Figure 4]

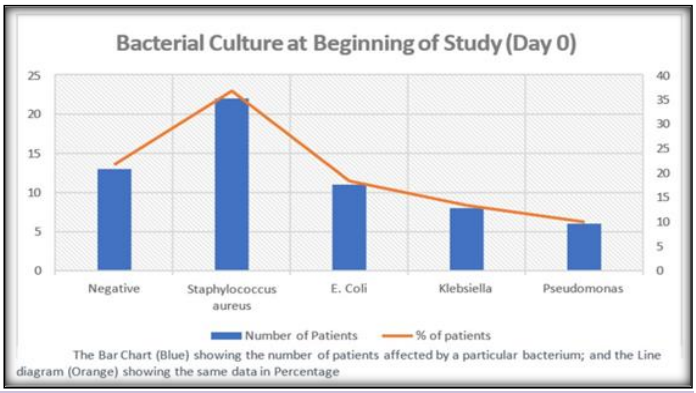

Figure 4: Bar chart showing the bacterial culture on Day 0 of the wound

Wound Healing: The mean wound area at the beginning and end of treatment was calculated using the photographic measurement technique.

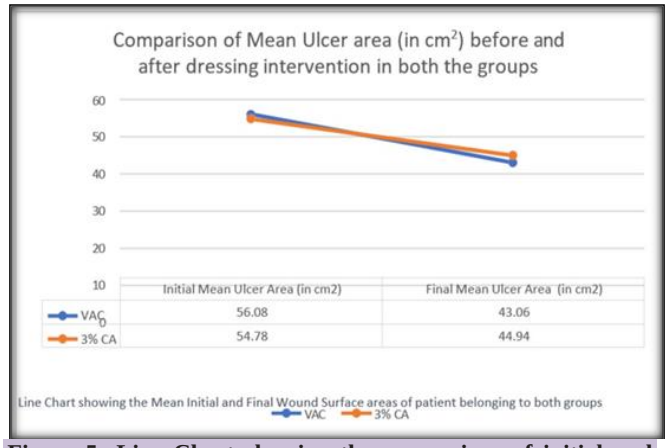

Figure 5: Line Chart showing the comparison of initial and final wound surface area of both the groups

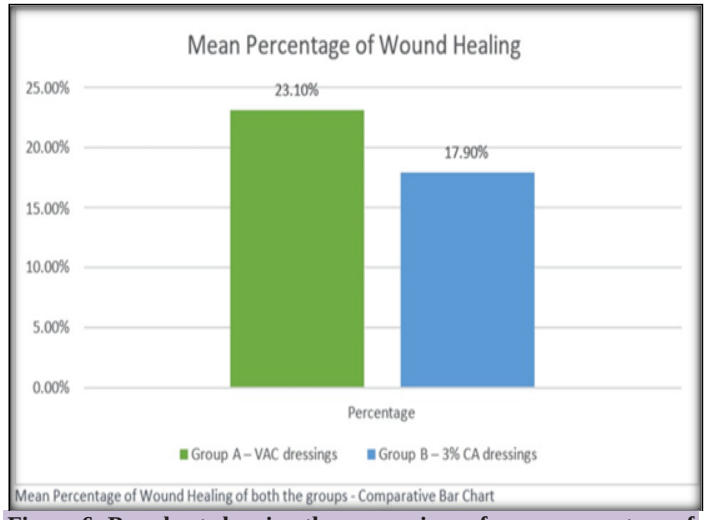

Figure 6: Bar chart showing the comparison of mean percentage of wound healing between both the groups.

Group A (VAC therapy) Initial wound area: 56.08 cm² Final wound area: 43.06 cm². *Group B* (3% Citric Acid) Initial wound area: 54.78 cm² Final wound area: 44.94 cm² [Figure 5].

The mean percentage reduction in wound size is shown in [Table 1]

Table 1: Group Statistics – Percentage of Wound Healing

	Modality Chosen	Sample size (n)	Mean	Std. Deviation	Std. Error Mean
Percentage of Wound Healing	VAC	30	23.10	4.262	0.778
	3% CA	30	17.90	3.177	0.582

Statistical analysis showed $p < 0.001$, [Table 2], indicating a highly significant difference between the two groups. VAC therapy demonstrated superior wound healing compared to 3% citric acid dressing. [Figure 6].

Table 2: Comparison between Group A and Group B in terms of Percentage of wound healing

	Group A – VAC dressings	Group B – 3% Citric Acid dressings	'p' value	Statistical Test applied
Percentage of wound healing	23.1 ± 4.26	17.9 ± 3.17	<0.001	Independent samples t-test

Duration of Hospital Stay: The duration of hospital stay corresponded to the time required for formation of adequate granulation tissue. Mean hospital stay is shown in [Table 3]

Table 3: Group Statistics – Duration of Hospital Stay (in days)

	Modality Chosen	Sample size (n)	Mean	Std. Deviation	Std. Error Mean
Duration of Hospital Stay	VAC	30	14.30	2.366	0.432
	3% CA	30	19.40	3.979	0.727

Statistical tests revealed a statistically significant reduction in hospital stay among patients treated with VAC therapy. [Table 4, Figure 7]

Table 4: Comparison between Group A and Group B in terms of Duration of hospital stay

	Group A – VAC dressings	Group B – 3% Citric Acid dressings	'p' value	Statistical Test applied
Duration of Hospital Stay (in days)	14.3 ± 2.36	19.4 ± 3.97	<0.001	Independent samples t-test

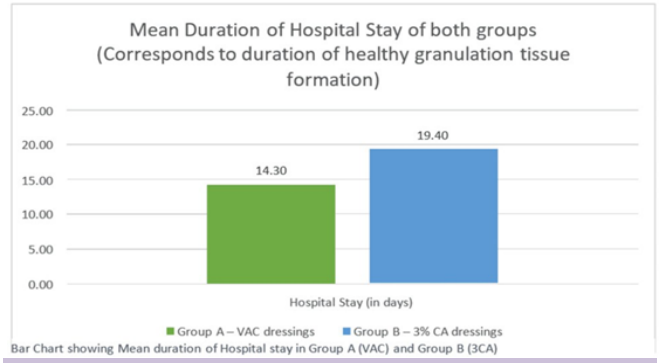

Figure 7: Bar chart showing the comparison of mean duration of hospital stay between both the groups

Discussion

This prospective study compared the efficacy of Vacuum Assisted Closure therapy and 3% citric acid dressings in the management of diabetic foot ulcers.

The mean age of patients in Group A was 54.2 years, while in Group B it was 55.6 years. These values were comparable between the two groups. Previous studies such as those by Margolis et al. have reported that diabetic foot ulcers are most commonly observed in individuals in the sixth decade of life.[17]

The observation of male predominance is consistent with reports from the National Health Service (UK) and studies by Purushottam et al, which also documented a higher prevalence of diabetic foot ulcers among males.[18] Patients in Group A had a mean duration of diabetes of9.28 years, while Group B had 9.7 years, with no statistically significant difference between the groups.

These findings are comparable with the Seattle Diabetic Foot Study conducted by Boyko et al., which reported an average duration of diabetes of 9.6 ± 1.9 years in patients developing diabetic foot ulcers.[19]

Several studies have demonstrated the effectiveness of citric acid in wound healing. Nagoba et al. made significant contributions in promoting the use of 3% citric acid as a cost-effective and safe method for wound management.[14,15,20-22] Histopathological evidence of citric acid promoting wound healing through fibroblast proliferation and neo-vascularization was reported by Nagoba et al.

Further studies have demonstrated the clinical effectiveness of citric acid dressings. Nagoba et al. reported complete healing in 50 out of 52 snake bite ulcers treated with 3% citric acid.[23] Hartalkar et al. reported significant reduction in ulcer size within three weeks of citric acid therapy.[15] Similarly, Sudhir Khichy et al. showed that citric acid dressings were more effective than povidone iodine dressings in wound management.[24]

On the other hand, numerous studies have established the benefits of VAC therapy in chronic wounds. Studies by Venturi et al., Chen et al., Saxena et al., and Plikaitis et al. reported that VAC therapy improves wound healing by removing protease-rich exudate, reducing bacterial load, and improving local microcirculation. [10,13,25,26]

Blume et al. conducted a multicenter randomized trial comparing NPWT with advanced moist wound therapy and demonstrated better outcomes with VAC therapy.[27] Similarly, Muhammad T.Sajid et al. reported superior wound healing with VAC therapy compared to advanced moist wound therapy in a large cohort of patients with diabetic foot ulcers.[28]

In the present study, VAC therapy showed significantly better outcomes in terms of percentage wound healing and duration of hospital stay compared with 3% citric acid dressings. The mean percentage wound reduction was 23.10% in the VAC group compared with 17.90% in the citric acid group.

Additionally, the duration of hospital stay was significantly shorter in the VAC group (14.3 days) compared to the citric acid group (19.4 days). Faster granulation tissue formation and improved wound bed preparation likely contributed to earlier readiness for definitive wound closure.

However, VAC therapy has certain limitations including higher cost, requirement of specialized equipment, and the need for trained personnel. These factors may limit its widespread application in resource-limited healthcare settings.

In contrast, 3% citric acid dressing is inexpensive, easily available, and simple to apply, making it a practical option in low-resource environments.

Limitations of the study:

The relatively small sample size may limit the ability to detect smaller differences between the two treatment groups and restrict the generalizability of the findings.

Conclusion

This prospective comparative study evaluated the efficacy of Vacuum Assisted Closure therapy and 3% citric acid dressing in the management of diabetic foot ulcers. A total of 60 patients were included and equally allocated into two groups. The study demonstrated that VAC therapy was significantly more effective than 3% citric acid dressings in promoting wound healing, with greater reduction in wound size and shorter duration of hospital stay. The findings suggest that VAC therapy enhances granulation tissue formation and accelerates the healing process in diabetic foot ulcers. However, its higher cost and requirement for specialized equipment may limit its widespread use in resource-constrained settings, where 3% citric acid dressing continues to be a safe, economical, and reasonably effective alternative. Further large-scale multi-centric studies are warranted to validate these findings and to establish standardized treatment protocols for diabetic foot ulcer management.

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Nil.

Conflicts of interest

There are no conflicts of interest.

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