

Impact of Minimally Invasive Surgical Techniques on Healing Time in Diabetic Foot Ulcers

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ABSTRACT

Background: Diabetic foot ulcers represent a frequent and grave complication of diabetes mellitus, frequently resulting in extended hospitalization, secondary infections, and limb loss. Recent surgical innovations have developed techniques which are less invasive in nature with the intent to improve healing outcomes while reducing complications.

Objective: To evaluate the effectiveness of minimally invasive surgical techniques on healing time and related outcomes in patients with diabetic foot ulcers.

Methods: This comparative study was carried out at the Department of General Surgery, Lady Reading Hospital, Peshawar, between January 2023 and January 2024. Out of the total 71 patients diagnosed with diabetic foot ulcers, two cohorts were formed: the first cohort received minimally invasive surgical treatment, whereas the latter underwent conventional open surgery. Information was gathered on the healing time, reduction of ulcer size, infection rate, duration of hospital stay, and overall satisfaction among patients. Data was analyzed statistically with SPSS version 25, using a significance threshold of $p < 0.05$.

Results: Patients treated with minimally invasive procedures had significantly shorter healing times (mean 5.4 weeks vs. 7.6 weeks, $p < 0.001$) and lower infection rates (14.3% vs. 33.3%, $p = 0.042$) compared to the conventional group. They also experienced shorter hospital stays and higher satisfaction levels. Although re-ulceration was less frequent in the minimally invasive group, the difference was not statistically significant.

Conclusion: Minimally invasive surgical techniques are effective in promoting faster healing and reducing infection risk in diabetic foot ulcers. These approaches offer a patient-friendly and efficient alternative to conventional surgery, particularly in healthcare settings aiming to improve surgical outcomes and resource utilization.

Keywords: Diabetic foot ulcer, minimally invasive surgery, healing time, wound infection, negative pressure wound therapy, patient outcomes

INTRODUCTION

Diabetes mellitus remains a prominent public health concern globally, with complications like diabetic foot ulcers significantly impacting patient quality of life and increasing healthcare costs. Foot ulcers will affect almost a quarter of individuals afflicted by diabetes at some point in their lives, and due to their chronic nature, they require prolonged treatment duration that often results in infection, necessitates hospitalization, and in worst case scenarios, amputation. This problem is worsened in many low- and middle-income countries due to late arrival to specialized clinics and a lack of access to specialized services.¹⁻³

Diabetic foot ulcers are treated with a systematic approach that includes careful wound management, controlling any potential infections, and surgical debridement. Many cases respond well to treatment; however, traditional open surgery tends to extend healing time, increases the risk of hospital acquired infections, and lengthens the duration of hospitalization. These drawbacks have focused attention on alternative treatment methods that are more minimally invasive and that put greater emphasis on both the clinical results and the comfort of the patient.⁴⁻⁶

In recent years, there has been a shift towards the consideration of minimally invasive surgical techniques as alternatives for managing complex wounds. They include but are not limited to, endoscopic debridement, percutaneous drainage, as well as negative pressure wound therapy. The goal of all such procedures is the preservation of the wound's aseptic barrier while simultaneously promoting granulation tissue formation and local blood flow.⁷⁻⁹

Although initial trials were promising, minimally invasive techniques have not been adopted in diabetic foot management,

especially in low-resource settings. Further comparative studies assessing the real-world impact of these methods are still warranted.¹⁰⁻¹²

This study was undertaken to assess the impact of minimally invasive surgical approaches on healing time and related outcomes in patients with diabetic foot ulcers, with the aim of providing evidence to support broader clinical use.

METHODOLOGY

This observational, comparative study was carried out at the department of General Surgery, Lady Reading Hospital, Peshawar, for the duration of one year, from January 2023 to January 2024. The focus was on evaluating the effect of surgical intervention type minimally invasive versus conventional on the healing time of diabetic foot ulcers. An ethical review was completed, and approval was granted by the institutional review board prior to the study commencement. All subjects provided written informed consent prior to study enrolment.

Using a non-probability consecutive sampling method, a total of 71 patients diagnosed with diabetic foot ulcers were included in the study. Patients were included in the study if they had Type 1 or Type 2 Diabetes Mellitus and had foot ulcers graded as Wagner I to IV. Patients with diabetic foot ulcers capped at stage IV, non-diabetic ulcers, immunocompromised conditions such as advanced malignancy or HIV, and critical limb ischemia requiring vascular bypass were excluded.

Each participant underwent a detailed clinical assessment, including ulcer type (neuropathic, ischemic, or mixed), ulcer size, duration, depth, and presence of infection. Relevant investigations such as HbA1c levels, ankle-brachial index (ABI), and wound cultures were obtained where appropriate. Demographic data including age, gender, BMI, smoking history, and diabetes duration were also recorded.

The patients were divided into two groups based on the type of surgical management received:

- **Group A:** Underwent minimally invasive surgical techniques, including endoscopic debridement, percutaneous drainage, and negative pressure wound therapy (NPWT) as needed.
- **Group B:** Received conventional open surgical debridement and standard wound care practices.

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Wound healing was monitored through serial examinations, and progress was documented weekly until complete epithelialization occurred. The primary outcome was the mean healing time, defined as the duration in weeks from the first surgical intervention to complete wound closure. Secondary outcomes included reduction in ulcer size, incidence of post-operative infections, length of hospital stay, and re-ulceration rates within 3 months. Patient satisfaction was also recorded using a 5-point Likert scale at the end of the treatment period.

All data were analyzed using SPSS version 25. Continuous variables were presented as mean ± standard deviation and compared using independent sample t-tests. Categorical data were expressed as frequencies and percentages and analyzed using chi-square tests. A p-value of <0.05 was considered statistically significant.

RESULTS

The demographic distribution showed that middle-aged individuals (40–60 years) formed the bulk of the study group, representing over half of the total participants. Males were more commonly affected than females in this diabetic foot ulcer cohort. Interestingly, nearly three-quarters of participants were either overweight or obese, which may have contributed to delayed healing. The majority had been living with diabetes for more than five years, indicating a chronic disease burden. A substantial number of participants were non-smokers, yet more than one-third still had a history of smoking, which is known to hinder microvascular circulation and wound repair.

Table 1: Demographic Characteristics of Participants (n = 71)

Variable	Category	Frequency (%)
Age	<40 years	12 (16.9%)
	40–60 years	38 (53.5%)
	>60 years	21 (29.6%)
Gender	Male	44 (62.0%)
	Female	27 (38.0%)
BMI	Normal	20 (28.2%)
	Overweight	31 (43.7%)
	Obese	20 (28.2%)
Duration of Diabetes	<5 years	18 (25.4%)
	5–10 years	30 (42.3%)
	>10 years	23 (32.3%)
Smoking Status	Yes	25 (35.2%)
	No	46 (64.8%)

In clinical terms, neuropathic ulcers were the most common type observed in this study, followed by a significant number of mixed-type ulcers. Ischemic wounds were relatively fewer, though still clinically important. Most ulcers were categorized as Grade I or II according to Wagner’s classification, suggesting earlier-stage presentation in many cases. Over half of the patients had clinical signs of infection upon presentation, which can complicate surgical management. One-third of the participants had experienced previous foot ulcers, indicating recurrent disease. Peripheral arterial disease was documented in almost 30% of patients, highlighting the vascular compromise common in diabetic foot conditions.

Table 2: Clinical Profile Related to Foot Ulcers

Variable	Category	Frequency (%)
Ulcer Type	Neuropathic	29 (40.8%)
	Ischemic	18 (25.4%)
	Mixed	24 (33.8%)
Wagner Grade	Grade I–II	42 (59.2%)
	Grade III–IV	29 (40.8%)
Presence of Infection	Yes	41 (57.7%)
	No	30 (42.3%)
Previous Foot Ulcer	Yes	26 (36.6%)
	No	45 (63.4%)
Peripheral Arterial Disease	Present	21 (29.6%)
	Absent	50 (70.4%)

Minimally invasive surgical techniques demonstrated a clear advantage in terms of healing time, with patients in this group recovering significantly faster than those who underwent conventional surgery. On average, ulcers healed in just over five weeks with the minimally invasive approach, compared to more than seven weeks with standard surgery. Reduction in ulcer size was also more pronounced in the minimally invasive group. Post-operative infections occurred more frequently in the conventional group, suggesting better sterile technique or wound care in the minimally invasive procedures. Although re-ulceration rates were slightly lower in the minimally invasive group, the difference did not reach statistical significance. Importantly, hospital stay was markedly shorter with minimally invasive surgery, reducing the burden on healthcare facilities.

Table 3: Comparison of Healing Outcomes

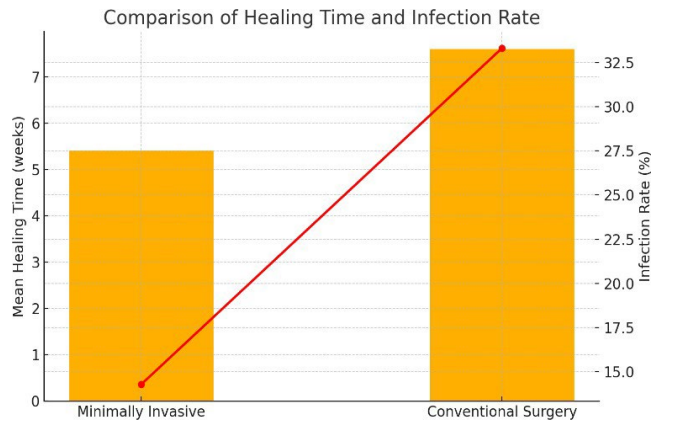
Outcome Measure	Minimally Invasive (n = 35)	Conventional Surgery (n = 36)	p-value
Mean Healing Time (weeks)	5.4 ± 1.2	7.6 ± 1.5	<0.001
Reduction in Ulcer Size (cm²)	85%	62%	0.002
Post-op Infection Rate	5 (14.3%)	12 (33.3%)	0.042
Re-ulceration in 3 months	2 (5.7%)	6 (16.7%)	0.138
Hospital Stay (days)	4.1 ± 1.3	6.3 ± 1.6	<0.001

Additional interventions played an important role in patient outcomes. Negative pressure wound therapy (NPWT) was utilized significantly more often in the minimally invasive group, which may have contributed to faster wound healing and fewer infections. Although the use of skin grafting was comparable between the two groups, patient satisfaction was notably higher in those who underwent minimally invasive procedures. This likely reflects reduced pain, quicker mobility, and shorter hospital stays. Higher satisfaction also suggests better overall acceptance of the procedure among patients.

Table 4: Adjunct Interventions and Patient Satisfaction

Variable	Minimally Invasive (n = 35)	Conventional Surgery (n = 36)	p-value
Use of NPWT	22 (62.9%)	10 (27.8%)	0.003
Use of Skin Grafting	9 (25.7%)	11 (30.6%)	0.645
Patient Satisfaction (Likert 4–5)	30 (85.7%)	21 (58.3%)	0.015

Figure 1: Graph Comparing Mean Healing Time (bar graph) and Infection Rate (line graph) between the Minimally Invasive and Conventional Surgery Groups.



DISCUSSION

The findings of this study strongly support the use of minimally invasive surgical techniques in the management of diabetic foot ulcers. Patients treated with these approaches experienced significantly faster healing times, shorter hospital stays, and

higher satisfaction scores compared to those managed with conventional surgery. These results align with emerging global evidence suggesting that less invasive interventions can enhance wound healing in diabetic patients by minimizing tissue trauma and improving post-operative recovery.

A comparable outcome was observed in a studies which showed that patients receiving negative pressure wound therapy in conjunction with minimally invasive debridement had notably shorter healing durations than those undergoing traditional wound care.¹³⁻¹⁵ Similarly, researches highlighted the benefits of modern wound care adjuncts such as NPWT in reducing infection rates and supporting granulation in diabetic foot ulcers, especially when paired with minimally traumatic surgical interventions.¹⁶⁻¹⁸ In our study, the infection rate in the minimally invasive group was markedly lower, a trend also noted in studies where minimally invasive procedures demonstrated superior infection control and ulcer resolution. This may be due to better preservation of surrounding tissue and reduced exposure of deeper structures, which lowers the risk of contamination during and after the procedure.¹⁹⁻²¹

Additionally, patient satisfaction in this study was significantly higher among those treated with minimally invasive techniques. This can be attributed not only to quicker recovery but also to less pain, smaller incisions, and reduced hospital stays all factors known to improve the patient's overall experience. This observation was consistent with studies which emphasized the importance of patient-centred outcomes in diabetic wound care, especially in relation to mobility and quality of life

While re-ulceration rates were lower in the minimally invasive group, the difference was not statistically significant. This suggests that long-term ulcer recurrence may be influenced by other factors such as glycemic control, footwear, and patient adherence to follow-up care, rather than surgical technique alone.

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Nonetheless, the present study contributes to a growing body of literature that supports the clinical and economic benefits of minimally invasive surgical strategies. In resource-limited settings, where prolonged hospitalizations and surgical complications impose additional burdens, these techniques can offer an effective and sustainable solution.

CONCLUSION

Minimally invasive surgical approaches offer a clear advantage over conventional techniques in the management of diabetic foot ulcers. They are associated with faster wound healing, fewer infections, reduced hospital stays, and greater patient satisfaction. Incorporating these methods into routine clinical practice can improve patient outcomes and reduce the burden on healthcare systems. Future studies with longer follow-up periods and larger sample sizes are recommended to evaluate their impact on ulcer recurrence and long-term limb salvage.

Authors' Contribution

AUK, SA: Concept & study design, data collection and drafting of the manuscript.

ST, HS: Data entry, statistical analysis, interpretation of the results.

HA: Manuscript editing and critical revision of the manuscript.

All authors approved the final version of the manuscript to be published.

Conflict of Interest

The authors declared no conflict of interest.

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Data Availability

Data is available with authors and can be provided on request.

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