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Original Article

Primary Partial Closure in Below-Knee Amputation for Diabetic Foot Disease: A Single-Arm Prospective Observational Study

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Abstract

Background: *Below-knee amputation (BKA) in advanced diabetic foot disease is often complicated by stump wound problems. The best closure strategy remains unresolved, and outcome data for primary partial closure (PPC), in which a dependent segment is left open for drainage, are sparse.*

Objective: *This study aims to describe wound-healing and short-term postoperative outcomes following primary partial closure in below-knee amputation for diabetic foot disease.*

Methods: *This single-arm prospective observational study was conducted at Ibrahim Cardiac Hospital & Research Institute, Dhaka, from January 2023 to December 2025. Sixty-four consecutive adults with type 2 diabetes (HbA1c ≤10%) undergoing non-emergency BKA all received PPC. Co-primary outcomes were complete healing within 90 days and time to healing. Secondary outcomes included surgical site infection (SSI), revision, re-amputation, systemic complications, hospital stay, and 30-day mortality.*

Results: *Mean age was 60.59 ± 10.42 years; 67.2% were male, and 92.2% were ASA III–IV. Two patients (3.1%) died within 30 days. Of 62 survivors at 90 days, 56 (90.3%) achieved complete healing, with a median time of 42 days (IQR 34–57). SSI occurred in 7.8%, stump revision in 7.8%, and above-knee re-amputation in 4.7%. At least one complication occurred in 18.8%. Mean hospital stay was 10.16 ± 4.83 days.*

Conclusion: *In this high-risk cohort, about nine in ten survivors healed within 90 days, with few conversions to above-knee amputations. Lacking a comparator and with wide confidence intervals, the study cannot establish superiority over other closure methods; comparative studies are needed.*

Keywords: Below-knee amputation; diabetic foot; primary partial closure; stump healing; surgical site infection; vascular surgery

Introduction

Diabetes mellitus is a heterogeneous metabolic disorder characterized by chronic hyperglycemia arising from defects in insulin secretion, insulin action, or both, and sustained hyperglycemia causes progressive damage to the eyes, kidneys, nerves, heart, and blood vessels[1]. Global

prevalence has risen steeply over recent decades. The Global Burden of Disease Study estimated 383 million people living with diabetes in 2016[2], while the International Diabetes Federation estimated 537 million adults living with diabetes in 2021[3].

Diabetic foot syndrome is among the most disabling of its complications, arising from the combined effects of peripheral neuropathy, peripheral arterial disease, impaired immunity and infection, and frequently culminating in chronic ulceration, tissue necrosis and lower-extremity amputation[4]. Peripheral neuropathy, foot deformity, callus formation and peripheral vascular disease each independently increase the risk of ulceration and subsequent limb loss[4].

Lower-extremity amputation remains the most devastating consequence of diabetic foot disease. Zhang et al. estimated that in 2016 approximately 131 million people worldwide, representing 1.8% of the global population, were living with diabetes-related lower-extremity complications, a composite prevalence estimate encompassing neuropathy, foot ulceration and amputation rather than a count of amputation events[2]. People with diabetes undergo lower-extremity amputation at rates many times higher than the general population, although reported relative risks vary widely across health systems and case definitions[5]. The principal indications for major amputation are severe soft-tissue infection, septic gangrene, osteomyelitis, non-healing ulceration and critical limb ischaemia when limb salvage is no longer achievable[1].

Major lower-limb amputation continues to represent a substantial global burden despite advances in wound care, revascularization and limb salvage[4]. Diabetes remains the leading cause of non-traumatic lower-extremity amputation worldwide, and the burden falls disproportionately on low- and middle-income countries, where delayed presentation, advanced infection, limited vascular assessment and constrained resources contribute to poorer outcomes[6]. Beyond physical disability, amputation carries profound psychological, social and economic consequences, including reduced mobility, loss of employment, depression, phantom limb pain and dependence on caregivers[7]. Mortality after major amputation is high: Walicka et al. reported 30-day mortality exceeding 11% in a population-based cohort[7], and Cascini et al. demonstrated that mortality continues to accrue over long-term follow-up[8].

The surgical management of the stump remains contested. After below-knee amputation, the surgeon must choose between immediate complete primary closure and a staged approach comprising guillotine amputation followed by delayed refashioning once infection is controlled. Complete primary closure offers fewer procedures and earlier rehabilitation but risks closing over a contaminated field; staged closure achieves sepsis control at the cost of a second anaesthetic, prolonged admission and greater expense[9,10]. The evidence favouring either strategy is mixed. Rehman et al. reported outcomes after primary closure comparable with staged closure in propensity-matched diabetic patients[9], and Cheun et al. found no excess of wound complications with primary closure where infection was controlled and tissue viability was satisfactory[10]. In a randomized trial confined to trauma amputations, Katiyar et al. found no significant difference between primary and delayed primary closure in either surgical site infection (23.3% versus 27.3%) or hospital stay (10.32 versus 11 days) [11].

Primary partial closure occupies the ground between these two strategies and, to our knowledge, has not been described systematically in diabetic foot disease. The stump is approximated under minimal tension while a dependent portion of the wound is deliberately left open, so that the soft-tissue envelope and muscle coverage of a primary closure are obtained while dependent drainage is preserved and the closed compartment that favours deep infection is avoided. The open segment is subsequently closed by delayed suture once the wound is clean, or allowed to heal by secondary intention. The rationale is mechanical rather than pharmacological, and it is most relevant where infection is established, but the soft-tissue envelope remains viable, which

is the commonest situation in diabetic foot disease in resource-constrained settings, where repeated anaesthetics and prolonged admission carry substantial cost[12]. Evidence comparing closure strategies after major amputation remains limited, particularly in South Asian populations, and existing series differ markedly in patient selection, severity of infection and vascular assessment[13] Therefore, this study aims to describe the wound-healing and short-term postoperative outcomes achievable with primary partial closure in patients undergoing below-knee amputation for diabetic foot disease.

Methods

This comparative cross-sectional study was conducted in the Department of Forensic Medicine, Rajshahi Medical College Hospital, Rajshahi, Bangladesh, from July 2019 to July 2020. A total of 36 suspected narcotic exposure cases were included in the study. Blood and urine samples were collected from suspected cases referred for forensic examination, in accordance with standard medico-legal procedures. Cases with adequate sample volume, proper labeling, and complete medico-legal documentation were included. Decomposed, contaminated, improperly preserved, or insufficient samples were excluded.

Blood samples were collected in clean, sterile containers with appropriate preservative where required, while urine samples were collected in sterile containers. All samples were labeled, sealed, and preserved, maintaining chain-of-custody principles. Each sample was tested using commercially available rapid antigen test kits for commonly abused narcotic substances, including methamphetamine/Yaba, cannabis/THC, opiates/codeine-related substances, benzodiazepines, and cocaine. Test procedures were performed according to the manufacturer's instructions. Results were recorded as positive, negative, or invalid. Invalid tests were repeated where possible, and unresolved invalid results were excluded from diagnostic accuracy analysis.

Rapid antigen test results were compared with confirmatory forensic testing, such as GC-MS, LC-MS/MS, HPLC, or other standard laboratory-based chemical analyses, as available. Sensitivity, specificity, positive predictive value, negative predictive value, accuracy, and agreement rate were calculated. Data were checked, coded, and analyzed using standard statistical methods. Categorical variables were expressed as frequency and percentage. Agreement between rapid antigen test kits and confirmatory methods was assessed using the kappa statistic; p-values <0.05 were considered statistically significant. Ethical approval was obtained from the concerned authority, and confidentiality of all medico-legal records was maintained.

Results

Table 1. Demographic characteristics of the study participants (N = 64)

Variables	Category	n (%) or mean ± SD
Age (years)	Mean age	60.59 ± 10.42
	30–40 years	4 (6.3)
	41–50 years	12 (18.8)
	51–60 years	21 (32.8)
	>60 years	27 (42.2)
Sex	Male	43 (67.2)
	Female	21 (32.8)

Of the 64 participants, the mean age was 60.59 ± 10.42 years, with the largest proportion (42.2%) aged over 60 years. Overall, 67.2% were male, while 32.8% were female, indicating a

predominance of older male patients undergoing below-knee amputation for diabetic foot disease.

Table 1 shows that, regarding clinical characteristics, the mean duration of diabetes was 13.8 ± 6.1 years, while hypertension was the most common comorbidity, affecting 60.9% of participants. Ischaemic heart disease and chronic kidney disease were present in 28.1% and 18.8%, respectively. Laboratory findings showed poor glycaemic control, with a mean HbA1c of 8.42 ± 0.91%, while the mean haemoglobin level was 9.61 ± 1.59 g/dL. Elevated leukocyte count was observed in 79.7%, elevated serum creatinine in 70.3%, and serum albumin below 3.5 g/dL in 54.7% of participant.

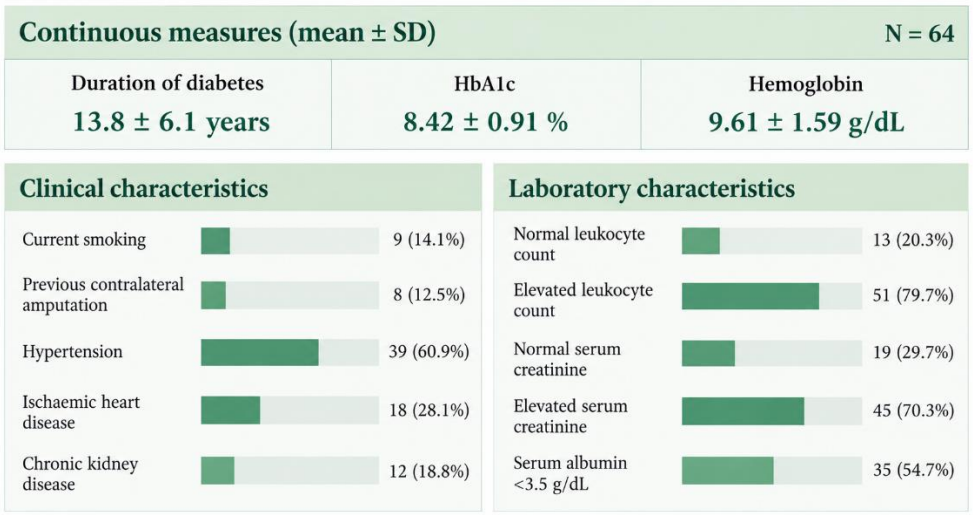


Figure 1. Clinical and laboratory characteristics (N = 64). Bars show prevalence; continuous data are mean ± SD

Figure 1 shows that, among the indications for amputation, wet gangrene with spreading infection was the most frequent, accounting for 45.3%, followed by infected ulcer with osteomyelitis in 31.3% and critical limb ischaemia with irreversible tissue loss in 23.4%. Regarding perioperative risk, 73.4% were ASA III and 18.8% were ASA IV. General anaesthesia was used in 81.3% of cases, while 18.8% received spinal anaesthesia.

Table 3. Perioperative characteristics of the study participants (N = 64)

Variables	Category	n (%)
Indication for amputation	Wet gangrene with spreading infection	29 (45.3)
	Infected ulcer with osteomyelitis	20 (31.3)
	Critical limb ischaemia with irreversible tissue loss	15 (23.4)
ASA physical status	ASA I–II	5 (7.8)
	ASA III	47 (73.4)
	ASA IV	12 (18.8)
Type of anaesthesia	General anaesthesia	52 (81.3)
	Spinal anaesthesia	12 (18.8)

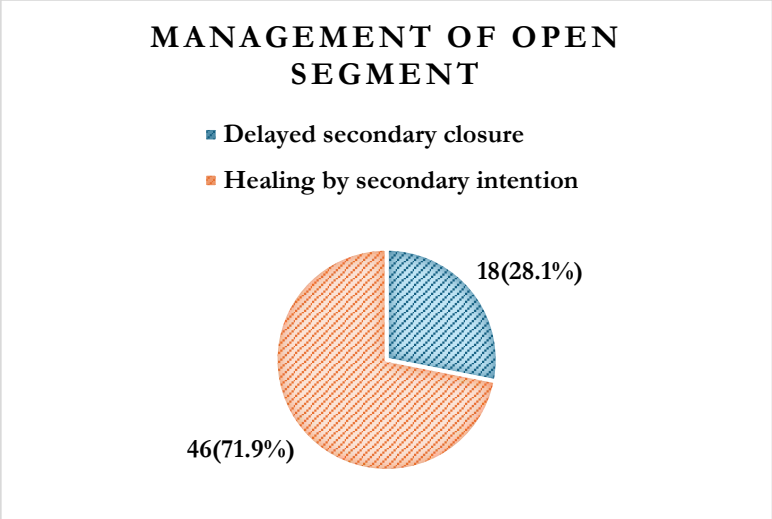


Figure 2: Subsequent management of the initially open segment following primary partial closure

Figure 2 shows that, following primary partial closure, the initially open segment healed predominantly by secondary intention in 71.9% of patients. Delayed secondary closure was performed in the remaining 28.1%, indicating that most open wound segments were allowed to granulate and heal without subsequent operative closure.

Table 4. Postoperative outcomes following primary partial closure

Outcome	Category	n (%) or mean ± SD
Wound-healing outcomes	Complete healing within 90 days	56 (90.3)
	Wound not completely healed at 90 days	6 (9.7)
	Time to complete healing (days)	42 (34–57)
Healing	Within 30 days	12 (19.4)
	Within 31–60 days	37 (59.7)
	Within 61–90 days	7 (11.3)
Systemic complications	Any systemic complication	7 (10.9)
	Sepsis	3 (4.7)
	Postoperative bleeding	2 (3.1)
	Acute kidney injury	3 (4.7)
Local stump complications	Any local stump complication	9 (14.1)
	Surgical site infection	5 (7.8)
	Stump-edge necrosis	4 (6.3)
	Wound dehiscence	3 (4.7)
	Stump revision at below-knee level	5 (7.8)
	Re-amputation at above-knee level	3 (4.7)
	Any complication (systemic or local)	12 (18.8)
Other outcomes	Postoperative hospital stays (days)	10.16 ± 4.83
	In-hospital mortality	2 (3.1)
	30-day mortality	2 (3.1)
	Lost to follow-up among survivors	0 (0.0)

Among the 62 surviving patients assessed for wound healing, 90.3% achieved complete below-knee stump healing within 90 days, while 9.7% remained incompletely healed. The median time to complete healing was 42 days (IQR: 34–57 days), and the largest proportion (59.7%) healed within 31–60 days. Systemic complications occurred in 10.9%, while local stump complications

developed in 14.1%. Surgical site infection occurred in 7.8%, stump-edge necrosis in 6.3%, and wound dehiscence in 4.7%. Overall, 18.8% experienced at least one postoperative complication; 7.8% required below-knee revision, and 4.7% underwent above-knee re-amputation. The mean postoperative hospital stay was 10.16 ± 4.83 days, while both in-hospital and 30-day mortality were 3.1%.

Discussion

In this single-arm prospective study, we evaluated outcomes of primary partial closure in 64 patients undergoing below-knee amputation for diabetic foot disease. Among the 62 patients surviving to 90 days, 56 (90.3%) achieved complete stump healing, with a median healing time of 42 days. Surgical site infection occurred in 7.8%, stump revision at the below-knee level in 7.8%, and conversion to above-knee amputation in 4.7%. Thirty-day mortality was 3.1%, while the mean postoperative hospital stay was 10.16 ± 4.83 days. Notably, these outcomes were observed despite substantial baseline physiological compromise, as 92.2% were ASA III–IV, mean haemoglobin was 9.61 g/dL, 79.7% had leucocytosis, 70.3% had elevated serum creatinine, and 54.7% were hypoalbuminaemic.

Demographically, the mean age was 60.59 years, about three-quarters of participants were older than 50 years, and 67.2% were male. Similar distributions have been reported previously[1,5,14], and Nather et al. also showed that major diabetic foot amputation predominantly affects older men with long-standing diabetes[13]. In addition, hypertension was present in 60.9%, ischaemic heart disease in 28.1%, and chronic kidney disease in 18.8%. Consistent with this pattern, the study by Ammar et al. identified renal impairment, cardiovascular disease, and uncontrolled infection as factors associated with limb loss and adverse surgical outcomes[15].

Regarding mortality, the observed 30-day rate of 3.1% was lower than the rate exceeding 11% reported by Walicka et al.[7]. However, this difference should be interpreted cautiously because only two deaths occurred and the present cohort excluded critically ill or surgically unsuitable patients. In contrast, population-based studies include a broader spectrum of emergency and high-risk amputations. Moreover, the study by Cascini et al. demonstrated continuing mortality after major amputation beyond the early postoperative period[8], while the study by Francia et al. documented substantial mortality associated with diabetic foot complications[16]. Therefore, 90-day follow-up cannot characterize long-term survival.

Regarding wound healing, complete healing within 90 days in 90.3% of survivors represents the principal finding. Nevertheless, the authors excluded patients with inadequate perfusion for below-knee healing, thereby selecting participants with better healing potential. Furthermore, most published comparisons involve complete primary closure or staged closure rather than primary partial closure. In propensity-matched diabetic patients, Rehman et al. found primary closure comparable with staged closure[9], while Cheun et al. reported acceptable outcomes after primary closure when infection was controlled and tissue viability was satisfactory[10]. These findings are supportive but remain indirect.

Regarding wound infection, surgical site infection occurred in 7.8%, lower than the 23.3% after primary closure and 27.3% after delayed primary closure reported by Katiyar et al.[11]. However, that randomized study involved traumatic crush-injury amputations rather than diabetic foot disease, making direct comparison inappropriate because of differences in perfusion, comorbidity, contamination, and microbiology. In addition, infection after partial closure depends on the diagnostic definition, because an intentionally open segment may become colonized without meeting clinical criteria for surgical site infection.

Regarding stump preservation, above-knee re-amputation was required in 4.7%, while the knee joint was preserved in 95.3%. Progressive stump ischaemia and uncontrolled deep infection

accounted for the failures. Similar mechanisms were described by Wong et al., where persistent infection, inadequate perfusion, and progressive ischaemia were major causes of stump failure and repeat amputation[17]. Preservation of the knee joint remains clinically important because transtibial amputation generally allows better rehabilitation and prosthetic mobility than transfemoral amputation.

The mean hospital stay was 10.16 ± 4.83 days. Among patients who developed complications, the stay was longer (16.38 ± 5.27 days) than among those without complications (8.74 ± 2.91 days). However, the single-arm design does not permit causal inference regarding the effect of closure technique on hospital stay. Katiyar et al. reported comparable durations, with mean stays of 10.32 and 11 days following primary and delayed primary closure, respectively[11]. In addition, Sailer et al. showed that multidisciplinary diabetic foot pathways can reduce hospital stay and amputation burden[18], emphasizing the importance of the overall perioperative pathway.

Regarding exploratory findings, patients who failed to heal within 90 days had higher mean HbA1c (9.11 ± 0.63% versus 8.32 ± 0.89%) and more frequent renal impairment (87.5% versus 67.9%). Because these comparisons involved very small numbers, lacked adjustment for confounders, and were not subjected to formal hypothesis testing, they should be considered hypothesis-generating rather than predictive.

Overall, primary partial closure was followed by complete stump healing within 90 days in approximately nine of ten survivors and preservation of the below-knee level in 95.3%. Although the technique has a plausible rationale by combining soft-tissue coverage with continued drainage, the present design cannot establish superiority or equivalence compared with complete primary or staged closure. Larger comparative studies with longer follow-up are required to determine its relative effectiveness and safety.

Limitations of the study

Several limitations should be acknowledged. Because no comparator group was included, we could not assess the relative effectiveness of primary partial closure versus other closure techniques. Selection of patients considered suitable for below-knee healing may have overestimated the observed healing rate. In addition, the small sample size, few outcome events, single-centre design, and non-blinded wound assessment limit precision and generalizability. The 90-day follow-up also precluded assessment of late stump complications, prosthetic use, ambulation, quality of life, and long-term mortality. Exploratory subgroup analyses were unadjusted and based on small numbers.

Conclusion

Primary partial closure following below-knee amputation for diabetic foot disease was associated with a high rate of stump healing and preservation of the below-knee level in appropriately selected patients. Most surviving patients achieved complete healing within 90 days, while rates of surgical site infection, stump revision, above-knee re-amputation, and early mortality remained relatively low. Although these findings suggest that primary partial closure is a feasible and potentially useful approach, larger comparative studies with longer follow-up are required to confirm its effectiveness and safety relative to other stump-closure techniques.

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Competing interests: None declared.

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