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Toe Amputations in Diabetic Feet - Does the Closure Technique Makes a Difference? A Retrospective Cohort Study

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Abstract

Background: Toe amputations are commonly performed for deep digital infections in patients with diabetic foot disease, with the goal of controlling infection while preserving limb length and function. Several surgical closure techniques are used, most commonly lateral-to-medial and plantar-to-dorsal flaps, yet evidence comparing their outcomes remains limited. Moreover, revision surgery after toe amputation is frequent in this high-risk population, and the relative contribution of surgical technique versus patient-related factors remains unclear.

Methods: This retrospective cohort study included 58 adult patients who underwent toe amputation for osteomyelitis or septic arthritis of the proximal or distal interphalangeal joints between 2018 and 2022 at a tertiary academic centre. Patients were treated using either a lateral-to-medial (n=25) or plantar-to-dorsal (n=33) closure technique. Demographic data, comorbidities, surgical details, and postoperative outcomes were collected. Primary outcomes included revision surgery and progression to more proximal amputation. Secondary outcomes included number of revisions and length of hospital stay. Subgroup analysis evaluated the effect of vascular catheterization in patients with severe peripheral arterial disease (PAD). Binary logistic regression was used to identify independent predictors of revision surgery.

Results: The cohort was characterized by advanced comorbidity: mean age was 74.5±9.2 years, all patients had diabetes mellitus, and 84% had PAD. Revision rates were high and similar between closure techniques (85% vs. 87%, p=0.65), with a mean of 2.4 revisions per patient. Progression to trans metatarsal or below-knee amputation did not differ between groups (p=0.87), nor did length of hospital stay. Among patients undergoing vascular catheterization for severe PAD, revision rates were comparable to those without catheterization (91% vs. 85%, p=0.68). Logistic regression identified diabetes mellitus (OR 1.60, 95% CI 1.10–2.40) and PAD (OR 1.30, 95% CI 1.02–1.68) as independent predictors of revision surgery, whereas closure technique was not.

Conclusion: In this high-risk diabetic population, closure technique following toe amputation did not significantly influence revision rates or limb progression. Outcomes were primarily driven by metabolic and vascular comorbidities, underscoring the importance of systemic optimization over local surgical factors.

Level of Evidence: Level III, Retrospective Cohort Study

Keywords: Toe amputation; Diabetic feet; Infection; Osteomyelitis; Forefoot ulcers; Surgical wound closure techniques; Peripheral artery disease (PAD); Wound complications

Data Availability Statement: Data generated or analysed during this study are not publicly available due to patient confidentiality, but are available from the corresponding author upon reasonable request.

Introduction:

Toe amputations are frequently performed in the management of deep infections involving the Proximal Interphalangeal (PIP) and Distal Interphalangeal (DIP) joints of the foot. These amputations serve a critical role in halting the progression of infection and preserving overall limb function. Early intervention with distal amputation may prevent the need for more extensive procedures, such as midfoot or hindfoot amputations, thereby maintaining greater ambulatory potential and quality of life for the patient [1]. This approach is particularly relevant in patients with diabetic foot disease, a major complication of diabetes mellitus associated with peripheral neuropathy, ischemia, and impaired wound healing. Diabetic foot ulcers precede approximately 85% of lower extremity amputations in diabetic individuals [2,3]. Diabetic foot ulcers are a complication experienced by 19 to 34 % of individuals with diabetes [3]. The global incidence of diabetes-related foot ulcers is estimated at 6.3%, with recurrence rates exceeding 40% within one year [4]. In these patients, timely and appropriately selected minor amputations such as toe disarticulations can reduce the risk of proximal progression, recurrent infections, and mortality. Preserving limb length through targeted surgical interventions is a cornerstone of diabetic limb salvage strategies, aimed at reducing the burden of disability and healthcare costs [5]. Multiple surgical techniques are available for toe amputations, each offering unique advantages and limitations. The most commonly employed approaches in current practice include: Side-to-side flap technique, which provides good soft tissue coverage and aims to maintain structural stability. Dorsal-plantar flap technique, which allows for more tailored soft tissue closure, particularly in cases where plantar or dorsal tissue quality varies (Figure 1) [6].

To date, no single method has demonstrated definitive superiority in terms of long-term outcomes. Comparative studies have failed to show significant differences in wound healing rates, infection recurrence, or the need for revision surgery among these techniques [7-8]. Moreover, selection of technique often depends on surgeon preference, patient-specific anatomical and physiological factors, and the extent of infection or ischemia. The purpose of this study is to evaluate whether one surgical technique demonstrates superior outcomes regarding wound healing, infection control, and the rate of revision surgery. Additionally, the study will assess whether the choice of technique has a measurable impact on the length of hospital stay. In this study, we aimed not only to describe outcomes following toe amputation but also to explore potential predictors of revision surgery following toe amputation. Given the multifactorial nature of postoperative complications, we sought to determine whether specific patient-related factors such as age, gender, Diabetes Mellitus (DM), or Peripheral Arterial Disease (PAD) contribute more significantly than others to the risk of revision. Identifying which variables, if any, have a stronger association with revision could help refine patient selection, optimize perioperative management, and improve long-term outcomes after toe amputation.

Figure 1: Type of amputations.

Figure 1. Shows illustrations of the three different toe amputation skin closure.

Methods

This was a retrospective cohort study conducted at a tertiary care academic medical centre specializing in diabetic foot management and limb preservation. The study included patients who underwent toe amputation between January 2018 and December 2022 due to deep infection involving the Proximal Interphalangeal (PIP) or Distal Interphalangeal (DIP) joints. Institutional Review Board (IRB) approval was obtained prior to data collection (2021-01568). Patients were eligible for inclusion if they met the following criteria: Age ≥18 years, confirmed diagnosis of osteomyelitis or septic arthritis involving the PIP or DIP joint of the toe based on imaging (MRI or radiograph) and/or intraoperative findings, Patients who underwent one of the two commonly used toe amputation techniques: side-to-side flap or dorsal-plantar flap. Exclusion criteria included: Previous partial foot or proximal amputations on the same limb, incomplete surgical or postoperative records, and follow-up period of less than 30 days. Surgical technique was identified through operative reports and categorized into two groups based on incision and flap design: Side-to-side flap or dorsal-plantar flap. All procedures were performed under sterile conditions in the operating room by board-certified orthopaedic foot and ankle surgeons, and intraoperative cultures were routinely obtained. The surgical closure technique was determined by the surgeon's discretion, soft tissue status and intraoperative judgment.

Demographic and clinical data were extracted from electronic medical records, including: Age, sex, Body Mass Index (BMI), Comorbidities (e.g., diabetes mellitus, peripheral arterial disease). Peripheral Arterial Disease (PAD) in this study was defined according to standard diagnostic criteria using the Ankle–Brachial Index (ABI). An ABI ≤ 0.90 was considered diagnostic of PAD, in accordance with established international guidelines [9-29]. The severity of PAD was further classified based on ABI values as follows: Normal:

1.00–1.3, Borderline: 0.91–0.99, Mild PAD: 0.7–0.9, Moderate PAD: 0.3–0.69, Severe PAD: <0.3, non-compressible (calcified) arteries: >1.30 [30]. Surgical data included: type of amputation and closure technique and need for reoperation or revision surgery. Postoperative outcomes included: Length of Hospital Stay (LOS), number of revisions and amputation level progression (e.g., midfoot or hindfoot conversion). Revision surgery was defined as the need for a return to the operating theatre within the study period due to postoperative complications, including wound infection, ischemia, or wound dehiscence. These events reflect failure of initial wound healing and necessitated surgical intervention to manage the compromised soft tissue or address underlying vascular insufficiency.

Post operative management

Postoperative management following toe amputation followed a standardized institutional protocol. All patients received targeted intravenous antibiotic therapy guided by intraoperative culture and sensitivity results, with the duration and type of antibiotic treatment determined according to the recommendations of the infectious disease specialist. Dressing changes were performed daily under sterile conditions, and patients were maintained non–weight bearing on the operated limb until suture removal, typically after adequate wound healing. During the hospital admission period, comorbidities were actively addressed with the aim of optimizing each patient's overall medical condition. Vascular consultations were obtained when indicated, and patients underwent catheter-based interventions or bypass surgery when required to improve distal perfusion. In addition, glycaemic control was closely monitored to maintain optimal blood glucose levels, and nutritional parameters such as serum albumin were evaluated and corrected when necessary. These measures were implemented to enhance wound healing potential and reduce the risk of postoperative complications. All patients remained hospitalized until clinically stable and ready for discharge, after which they were reviewed every two weeks in the outpatient clinic for wound assessment and monitoring of healing progress. In cases where revision surgery became necessary after initial discharge, patients were readmitted to the hospital for further surgical management and continuation of antibiotic therapy as indicated.

Statistical Analysis

Continuous variables were assessed for normality using visual inspection and Shapiro-Wilk tests. Variables that followed a normal distribution (e.g., age, BMI) were summarized using means and standard deviations and compared between groups using independent samples t-tests. Variables that deviated from normality (e.g., HbA1c, hospital stay) were summarized using medians and interquartile ranges and compared using the Mann–Whitney U test for two-group comparisons and the Kruskal–Wallis test for three-group comparisons. Categorical variables were summarized using frequencies and percentages and compared between groups using Fisher's exact test. A two-sided p-value < 0.05 was considered statistically significant. Binary logistic regression analysis was performed to identify independent predictors of revision surgery. The model included age, gender, Diabetes Mellitus (DM), and Peripheral Arterial Disease (PAD) as covariates. The dependent variable was revision status, categorized as revision versus no revision. Odds Ratios (ORs) with 95% Confidence Intervals (CIs) were calculated for each predictor to estimate the strength and direction of association. Model fit and explanatory power were assessed using Tjur's R^2, and overall predictive accuracy was compared against the baseline classification rate. All analyses were conducted using R version 4.5.0 (R Foundation for Statistical Computing, Vienna, Austria).

Results

There were 58 patients included in this study. Average age was 74.5 (SD= +/-9.2). There were 12 females (21%) and 46 males (79%). 100% of the patients had

Diabetes mellitus. Average Hba1c was 7.1 (Range- 5.5-7.9). Average albumin level was 2.9 (Range-2.2-4.1). 84% of the cohort population had PAD. Average BMI was 28.3 (SD=+/- 5.4). Average hospital stay was 14 days (Range- 9-23) **(Table 1).** The cohort was stratified according to the amputation closure technique: lateral-to-medial (N=25) and plantar-to-dorsal (N=33). The overall revision rate was markedly high in both the lateral to medial and plantar to dorsal closure groups, with 21 patients (85%) in the lateral to medial group and 29 patients (87%) in the plantar to dorsal group requiring at least one secondary procedure following the initial toe amputation. (p=0.65). In addition, the need for repeated revisions was also substantial in both groups, and no statistically significant difference was found between them (p = 1.000). On average, patients in each group underwent 2.4 revision (Range -2-6) procedures after their primary amputation **(Table 1)**. The number of proximal amputations, defined as progression to a midfoot (trans metatarsal amputation, TMA) or below-knee amputation (BKA) level, was similar across the two closure technique groups and did not demonstrate a statistically significant difference (p = 0.87). In the lateral-to-medial group, 3 patients (12%) underwent TMA and 2 patients (5%) underwent BKA. In the plantar-to-dorsal group, 4 patients (12%) required TMA and 2 patients (6%) required BKA **(Table 1).**

Patient demographics and comorbidities were comparable among the groups. The mean age ranged from 72.3 to 74.9 years (p = 0.814), with a predominance of male patients across all groups. Mean HbA1c levels were similar across groups (range 6.6–7.0; p = 0.812), as were BMI and albumin values (range BMI - 26.7–29.1; p = 0.138), (range Albumin -2.2-4.2; p=0.76) **(Table 1).** A total of 21 out of 58 patients (36.2%) in the study were active smokers at the time of surgery. The distribution of smokers was comparable among the two closure technique groups, with no statistically significant difference observed (*p* = 0.88). Specifically, there were 9 smokers (35%) in the lateral-to-medial group, 12 smokers (36%) in the plantar-to-dorsal group. This even distribution suggests that smoking status was balanced across the groups and therefore unlikely to have affected the differences in postoperative or healing outcomes **(Table 1).** Peripheral Vascular Disease (PVD) was most prevalent in the lateral-to-medial group (24 patients 95.0%) but did not differ significantly between amputation types (p = 0.233). The distribution of peripheral arterial disease (PAD) severity, classified according to ankle–brachial index (ABI) values, was similar across the two closure technique groups. In the lateral-to-medial group, where 24 of 25 patients (95%) were diagnosed with PAD, 9 patients (35%) had mild PAD (ABI 0.70–0.90), 10 patients (40%) had moderate PAD (ABI 0.40–0.69), and 5 patients (20%) had severe PAD (ABI <0.40). In the plantar-to-dorsal group, 27 of 33 patients (82%) had PAD, including 10 patients (30%) with mild, 11 patients (33%) with moderate, and 6 patients (18%) with severe PAD. This reflects a broadly even distribution of PAD severity across all groups, with no statistically significant difference between them (*p* = 0.77) **(Table 1).** Magnetic Resonance Imaging (MRI) was performed in all patients (100%) prior to surgery to confirm the diagnosis of osteomyelitis and to assess for septic arthritis involving the affected toe. The MRI findings were combined with the clinical findings, including the presence of a chronic sinus tract**,** exposed bone, a positive probe-to-bone test, and a swollen, erythematous, and warm toe often associated with an open ulcer. These classic clinical signs, supported by laboratory and radiographic evaluation (routine X rays and MRI), were considered sufficient to confirm the diagnosis and proceed with surgical management.

During the hospitalization period, all patients diagnosed with severe PAD underwent vascular catheterization in an effort to improve perfusion to the ischemic limb prior to or following toe amputation. Specifically, in the lateral-to-medial group, 5 patients (20%) had severe PAD and all 5 underwent catheter-based revascularization procedures. In the plantar-to-dorsal group, 6 patients (18%) were identified with severe PAD, and all 6 received vascular catheterization to enhance distal blood flow. **(Table 1).** A predefined subgroup analysis was performed to evaluate whether vascular catheterization influenced the risk of revision surgery. Eleven patients (19%) with severe Peripheral Arterial Disease (PAD) underwent catheter-based revascularization during the hospitalization period, while 47 patients did not require catheterization. Revision surgery occurred in 10 of 11 patients (91%) in the catheterization group compared with 40 of 47 patients (85%) in the non-catheterization group (risk difference 6%, 95% CI −15% to 27%; $p = 0.68$). The mean number of revision procedures was similar between patients who underwent vascular catheterization and those who did not (2.4 vs. 2.4 revisions, $p = 1.00$). Hospital stay was the similar between the groups. In the lateral to medial group average hospital stay was 22.3 days (range-15-30). In the plantar to dorsal group the average hospital stay was 22.9 days (range- 14-28). (p=0.23) **(Table 1).**

Table 1: Patient Demographics and Clinical Characteristics by Closure Technique.

Variable	Total (N=58)	Lateral-to-Medial (N=20)	Plantar-to-Dorsal (N=33)	Racket-type (N=5)	p-value
Age (years), mean ± SD	74.5 ± 9.2	72.3 ± 8.9	74.9 ± 9.1	74.5 ± 9.5	0.814
Sex, n (%male)	46 (79%)	16 (80%)	26 (79%)	4 (80%)	0.991
Diabetes mellitus, n (%)	46 (80%)	16 (80%)	27 (81.8%)	3 (60%)	0.549
HbA1c, mean (range)	7.1 (5.5–7.9)	6.9 (6.4–7.2)	7.0 (6.6–7.3)	6.6 (6.0–7.0)	0.812
Peripheral arterial disease, n (%)	49 (84%)	19 (95%)	27 (82%)	3 (60%)	0.233
BMI, mean ± SD	28.3 ± 5.4	29.1 ± 5.2	27.6 ± 5.1	26.7 ± 5.9	0.138
Hospital stay (days), Mean ± SD (range)	14 (9–23)	17.1 ± 10.3	18.2 ± 12.6	25.2 ± 17.9	0.506
Revision surgery (≥1 revision), n (%)	56 (97%)	19 (95%)	32 (97%)	5 (100%)	1.000
Number of revisions, Mean ± SD	1.6–1.7 ± 0.4	1.6 ± 0.5	1.7 ± 0.4	1.6 ± 0.3	0.999

Table 1 presents the demographic and clinical characteristics of the 58 patients included in the study, stratified by amputation closure technique (lateral-to-medial, plantar-to-dorsal, and racket-type). The groups were comparable in terms of age, sex distribution, comorbidities (diabetes mellitus, peripheral arterial disease), metabolic parameters (HbA1c, BMI), and hospital stay. No statistically significant differences were observed between the groups across any of the recorded variables.

Note: Continuous variables are expressed as mean ± standard deviation (SD) or range, and categorical variables as counts and percentages. Statistical significance assessed using one-way ANOVA or Fisher's exact test as appropriate.

A binary logistic regression analysis was performed to identify independent predictors of failed primary amputation requiring revision surgery, including age, sex, Diabetes Mellitus Type 2 (DMT2), and Peripheral Arterial Disease (PAD). In this analysis, both DMT2 and PAD emerged as independent risk factors for failure of primary amputation and subsequent need for revision. The presence of DMT2 was associated with a 1.6-fold increased risk of revision surgery (OR 1.60, 95% CI 1.10–2.40), while PAD increased the risk by a factor of 1.3 (OR 1.30, 95% CI 1.02–1.68). In contrast, age (OR 0.97, 95% CI 0.91–1.04), albumin levels (OR 0.62, 95% CI 0.67–3.02) and male sex (OR 0.72, 95% CI 0.17–3.02) were not significantly associated with revision risk. The overall model demonstrated modest explanatory power (Tjur's $R^2 = 0.093$) with a classification accuracy of 67.2%, compared with a baseline accuracy of 60.3%. These findings indicate that metabolic and vascular comorbidities, rather than demographic factors, play a central role in determining failure of primary amputation and the subsequent need for revision surgery in this cohort **(Table 2) (Figure 2).**

Table 2: Peripheral Arterial Disease (PAD) Severity and Diagnostic Workup by Closure Technique.

Variable	Lateral-to-Medial (N=20)	Plantar-to-Dorsal (N=33)	Racket-Type (N=5)	p-value
Patients with PAD, n (% of group)	19 (95%)	27 (82%)	3 (60%)	0.233
PAD Severity (by ABI), n (% of group)				
Mild (ABI 0.70–0.90)	7 (35%)	10 (30%)	1 (20%)	
Moderate (ABI 0.40–0.69)	8 (40%)	11 (33%)	1 (20%)	
Severe (ABI <0.40)	4 (20%)	6 (18%)	1 (20%)	0.77
Patients undergoing vascular catheterization (for severe PAD), n (% of group)	4 (20%)	6 (18%)	1 (20%)	—
MRI performed for diagnosis (osteomyelitis/septic arthritis), n (% of total)	—	—	—	10/58 (17%)
Diagnosis established clinically (sinus tract, exposed bone, probe-to-bone positive, ulcer), n (% of total)	—	—	—	48/58 (83%)

Table 2 summarizes the distribution and severity of peripheral arterial disease (PAD) among the three amputation closure technique groups, based on ankle–brachial index (ABI) classification. It also includes the number of patients undergoing vascular catheterization for severe PAD and the diagnostic methods used to confirm infection prior to surgery.

Note: PAD classified according to ankle–brachial index (ABI): mild 0.70–0.90, moderate 0.40–0.69, severe <0.40. All patients with severe PAD underwent vascular catheterization prior to or following amputation to improve distal perfusion. MRI was performed in 10 patients to confirm osteomyelitis or septic arthritis; all other cases were diagnosed clinically.

Figure 2: Mean total revisions by type of amputation.

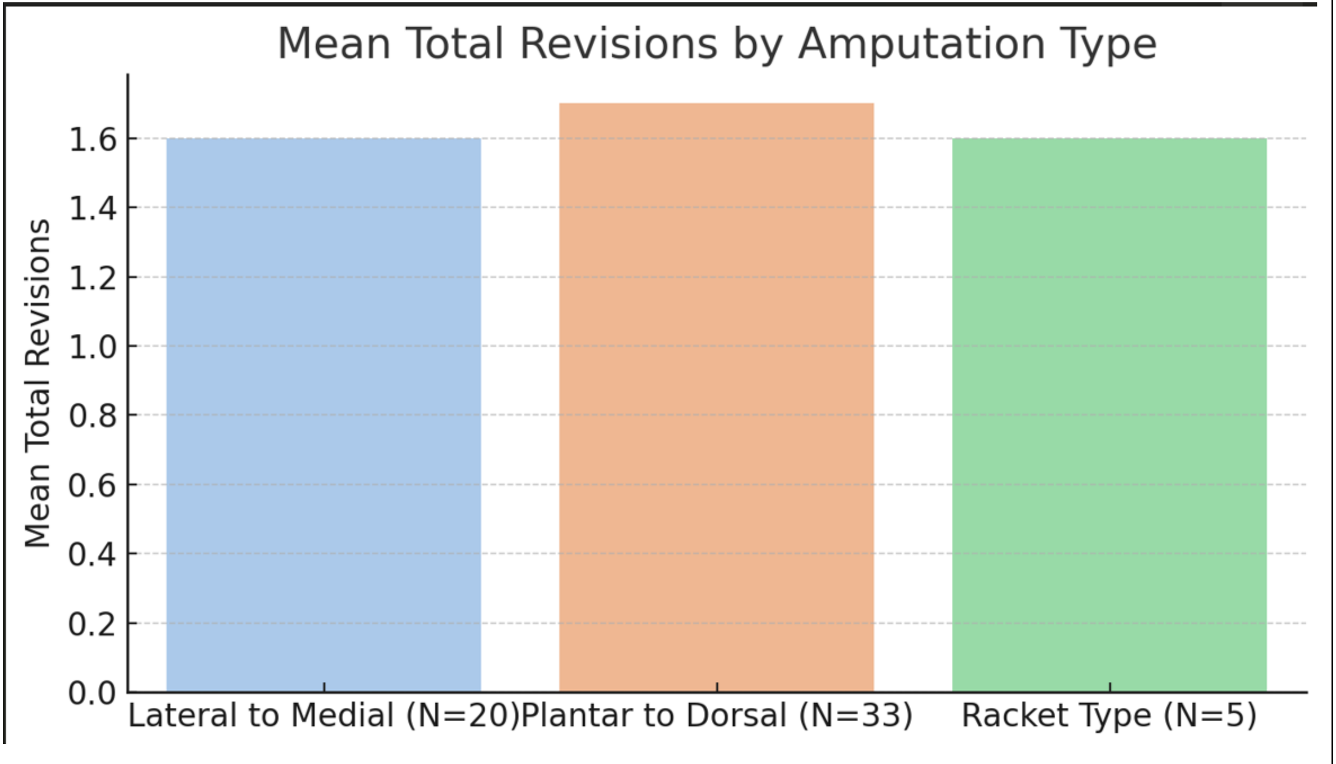

Figure 2: Mean number of revisions per patient by amputation type.

Discussion

Toe amputations are a critical component in the treatment of localized forefoot infections, especially among patients with diabetes. When performed early, these procedures can prevent infection from progressing to the midfoot or hindfoot, helping to preserve limb function and mobility [1]. Diabetic foot ulcers, which precede the majority of lower limb amputations, are associated with neuropathy, ischemia, and impaired healing [3,4]. In this context, limited amputations such as toe disarticulations are central to limb preservation strategies [5]. Several surgical techniques exist for toe amputation closure, including lateral-to-medial and plantar-to-dorsal. While each offers theoretical advantages depending on tissue condition and surgeon preference, no method has demonstrated clear superiority in existing literature [7,8]. This study aimed to evaluate whether any of these approaches was associated with better outcomes in terms of revision rates, infection control, and hospital stay duration. Our analysis demonstrated no statistically significant differences between the lateral-to-medial and plantar-to-dorsal closure techniques with respect to key clinical and postoperative outcomes. The mean number of revision surgeries was comparable between groups, with patients in both cohorts requiring an average of 2.4 revision procedures following primary toe amputation ($p = 1.000$). Similarly, duration of hospitalization did not differ significantly, averaging 22.3 days in the lateral-to-medial group and 22.9 days in the plantar-to-dorsal group ($p = 0.23$). Demographic and metabolic variables, including age, HbA1c levels, body mass index, serum albumin, smoking status, and sex distribution, were also well balanced between groups, indicating that baseline characteristics were unlikely to confound comparisons between closure techniques.

The overall revision burden observed in this cohort was substantial, with 85% of patients in the lateral-to-medial group and 87% in the plantar-to-dorsal group requiring at least one secondary surgical intervention (p = 0.65). Rates of repeated revisions were similarly high and did not differ significantly between groups. Progression to more proximal amputations, including trans metatarsal or below-knee amputation, occurred at comparable rates in both cohorts (p = 0.87), further supporting the absence of a technique-dependent effect on limb-salvage outcomes. The high incidence of revision surgery in this study is best interpreted in the context of the severe comorbidity profile of the study population. All patients carried a diagnosis of diabetes mellitus, with a mean HbA1c of 7.1, and the majority (84%) had documented peripheral arterial disease. In addition, nutritional compromise was common, as reflected by a mean serum albumin level of 2.9. These factors are well recognized contributors to impaired wound healing, infection, and failure of primary amputation. Diabetes-related microvascular disease, neuropathy, and immune dysfunction substantially increase the risk of delayed healing and recurrent infection, while PAD compromises distal tissue perfusion and exacerbates ischemia at the surgical site [1]. The effect of vascular catheterization on outcomes could not be definitively determined in this study. Although revision rates were similar between patients who underwent revascularization for severe Peripheral Arterial Disease (PAD) and those who did not require catheterization, this finding should be interpreted cautiously. Patients with severe PAD would ordinarily be expected to experience higher rates of wound complications, non-healing, and revision surgery due to impaired limb perfusion. The absence of increased revision rates in this subgroup may therefore suggest a potential beneficial effect of revascularization in mitigating the adverse impact of severe ischemia, as supported by prior studies demonstrating improved wound healing and limb salvage following targeted revascularization in diabetic foot patients. [12,13]. However, given the small sample size and retrospective design of the present study, this observation remains hypothesis-generating rather than conclusive. Larger prospective studies are required to better define the role of revascularization in reducing revision risk after diabetic toe amputation. Multivariable logistic regression analysis further supported the central role of these systemic comorbidities. Both diabetes mellitus type 2 and peripheral arterial disease emerged as independent predictors of failed primary amputation requiring revision surgery. Diabetes increased the risk of revision by a factor of 1.6 (OR 1.60, 95% CI 1.10–2.40), while PAD conferred a 1.3-fold increased risk (OR 1.30, 95% CI 1.02–1.68). In contrast, age, albumin levels and sex were not significantly associated with revision risk. Although the overall model demonstrated modest explanatory power, these findings underscore that metabolic and vascular disease rather than surgical closure technique are the dominant factors of adverse outcomes in this high-risk population.

Taken together, these results suggest that in patients undergoing toe amputation for infection or osteomyelitis in the setting of uncontrolled diabetes and PAD, the choice of closure technique alone does not substantially influence the likelihood of revision or limb progression. Instead, outcomes appear primarily dictated by the severity of systemic disease and compromised local biology, emphasizing the importance of aggressive vascular optimization, metabolic control, nutritional support, and close postoperative surveillance when managing this challenging patient population. In our cohort, diabetes mellitus and Peripheral Arterial Disease (PAD) frequently coexist, and both significantly influence wound healing and surgical outcomes. For this reason, PAD was not excluded, as this would not reflect the real-world clinical population in which these conditions often overlap. While PAD undoubtedly contributes to wound complications, its inclusion enhances the external validity of our findings by presenting outcomes in a representative, high-risk group of patients **[14].**

The existing literature comparing skin closure techniques following toe amputation remains limited and inconclusive. Several small studies have explored differences between primary closure, secondary intention healing, and local flap coverage, but none have definitively demonstrated superiority in terms of postoperative outcomes such as revision surgery, infection rates, or wound healing complications **[15].** While primary closure is commonly favoured for its simplicity and faster initial healing, it may carry higher risks of wound dehiscence or infection in ischemic or diabetic patients **[14].** Conversely, healing by secondary intention or use of flaps can reduce tension at the closure site but may prolong healing time and require closer follow-up. Overall, current evidence suggests that the choice of closure technique should be individualized, considering patient comorbidities, vascular status, and soft tissue conditions, as no single approach has consistently shown superior outcomes across large patient cohorts **[16-17].** High-quality, prospective comparative studies are still needed to establish optimal closure strategies after toe amputation. Management of patients with diabetic foot pathology is inherently complex, as multiple systemic and local factors interact to influence wound healing, infection control, and overall surgical success. Glycaemic control, peripheral perfusion, nutritional status, neuropathy, infection burden, and the extent of tissue loss frequently coexist in this population, making it difficult to isolate the relative contribution of individual variables to postoperative outcomes. In the present study, multivariable logistic regression analysis demonstrated that metabolic and vascular comorbidities play a central role in determining failure of primary toe amputation. Specifically, diabetes mellitus type 2 and peripheral arterial disease emerged as independent risk factors for failed primary amputation requiring revision surgery. Diabetes was associated with a 1.6-fold increased risk of revision, while PAD conferred a 1.3-fold increased risk, underscoring the detrimental effect of impaired microvascular and macrovascular perfusion on wound healing and infection clearance. These findings are consistent with the well-established pathophysiological mechanisms of diabetic microangiopathy, neuropathy, and immune dysfunction, as well as ischemia-related tissue compromise associated with PAD. In contrast, demographic factors such as age and sex were not significantly associated with revision risk, suggesting that biological disease burden rather than patient demographics drives outcomes in this setting. The high prevalence of diabetes and PAD in this cohort likely explains the substantial overall revision rate observed, regardless of closure technique. Importantly, these findings suggest that even with optimized surgical technique and standardized postoperative care, systemic disease severity may outweigh local technical factors in determining outcomes following toe amputation. This observation aligns with prior literature indicating that vascular status and metabolic control are among the strongest predictors of limb salvage and wound durability in diabetic foot surgery. Taken together, the results highlight the multifactorial nature of amputation failure while emphasizing the dominant influence of metabolic and vascular pathology. They also reinforce the importance of aggressive perioperative optimization, including vascular assessment and revascularization when indicated, strict glycaemic control, and nutritional support. Larger prospective studies are warranted to further refine risk stratification and to determine whether targeted interventions addressing these systemic factors can meaningfully reduce revision rates in this high-risk population **[30-33].**

This study has several limitations that should be acknowledged. First, its retrospective design is inherently subject to selection bias and reliance on the accuracy of existing medical records **[18].** To mitigate this, all consecutive eligible patients were included, and data were extracted systematically from operative reports, inpatient records, laboratory results, imaging studies, and follow-up documentation. Second, although the cohort included 58 patients, which is relatively large for a single-centre diabetic foot amputation study, the sample size remains modest and may limit statistical power, particularly for detecting small differences between closure techniques. Accordingly, the lack of statistically significant differences between groups should not be interpreted as equivalence **[19].** Third, the choice of amputation closure technique was not randomized but determined by the treating surgeon based on intraoperative findings, soft-tissue viability, infection extent, and vascular status. While this introduces potential confounding, it accurately reflects real-world clinical decision-making in diabetic foot surgery and enhances the external validity of the findings. Importantly, baseline demographics, metabolic parameters, nutritional status, smoking prevalence, and PAD severity were comparable between groups, reducing the likelihood that selection bias alone explains the observed outcomes **[20-25].** Another limitation is the uniformly high prevalence of diabetes mellitus and peripheral arterial disease in the study population. While this limits generalizability to lower-risk cohorts, it represents the patient population most commonly encountered in tertiary diabetic foot referral centres and provides valuable insight into outcomes in a severely comorbid group. Finally, despite standardized perioperative care and aggressive vascular management, the study design does not allow assessment of the impact of temporal changes in medical optimization or postoperative wound care strategies on revision risk **[26, 27].** Despite these limitations, the findings suggest that closure technique alone is unlikely to be the primary determinant of outcome following toe amputation in patients with advanced diabetic foot disease. The consistently high revision rates across both closure methods highlight the dominant role of systemic factors, particularly diabetes and peripheral arterial disease, in influencing healing and limb preservation **(Figure 3-5).**

Figure 3: Mean Hospital Stay.

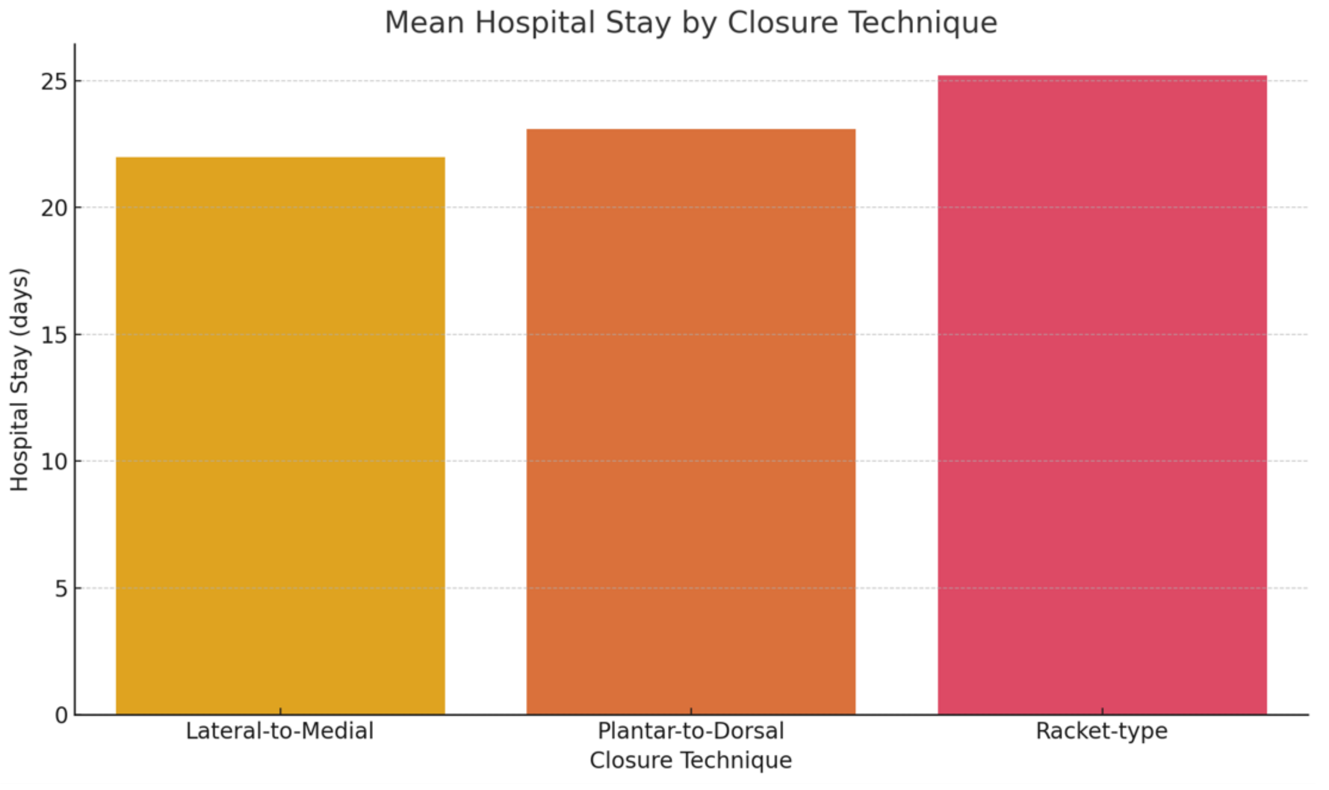

Figure 3: Mean hospital stay by amputation type.

Patients with racket-type closure had the longest hospital stay, followed by plantar-to-dorsal and lateral-to-medial groups.

Figure 4: Diabetes Mellitus Prevalence.

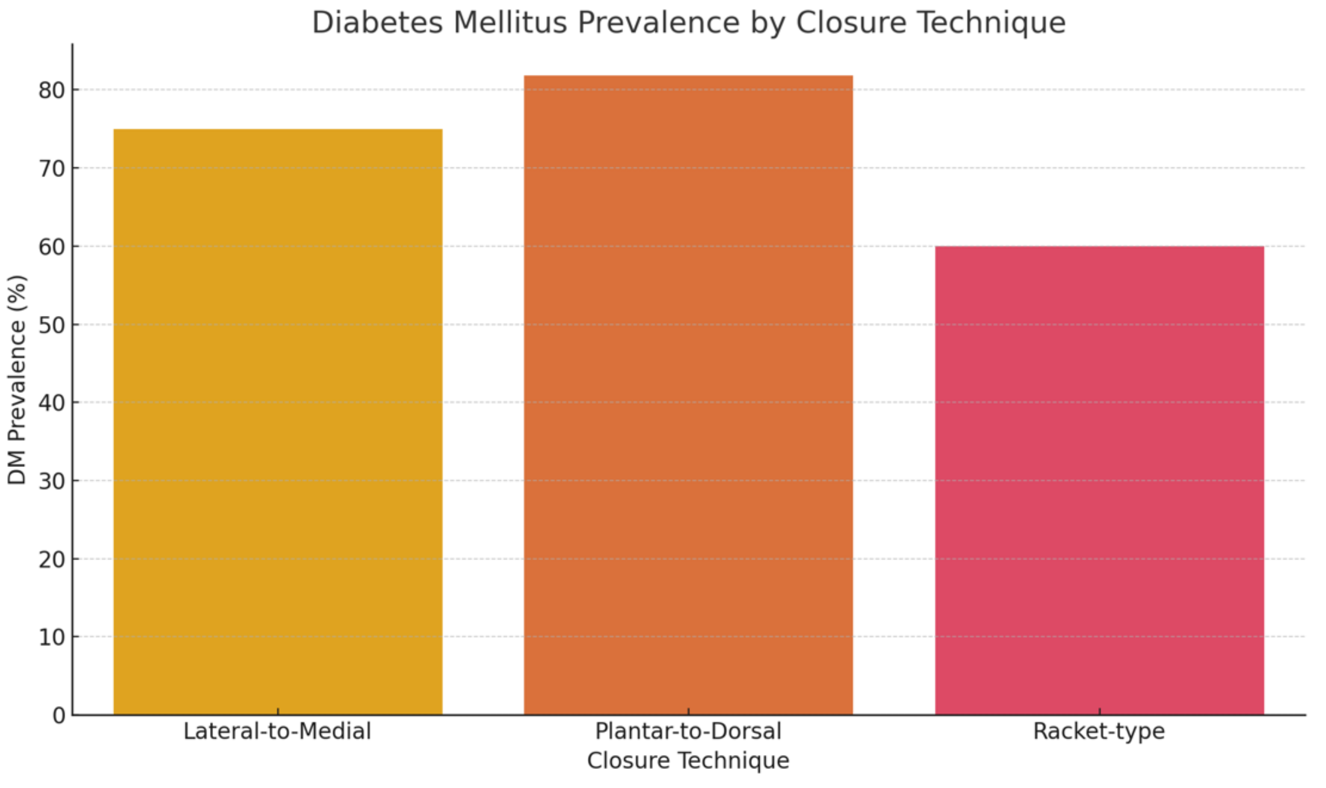

Figure 4: Prevalence of diabetes mellitus by amputation type.

Diabetes was most prevalent in the plantar-to-dorsal group, followed by lateral-to-medial and racket-type groups.

Figure 5: Predictors of revision surgery

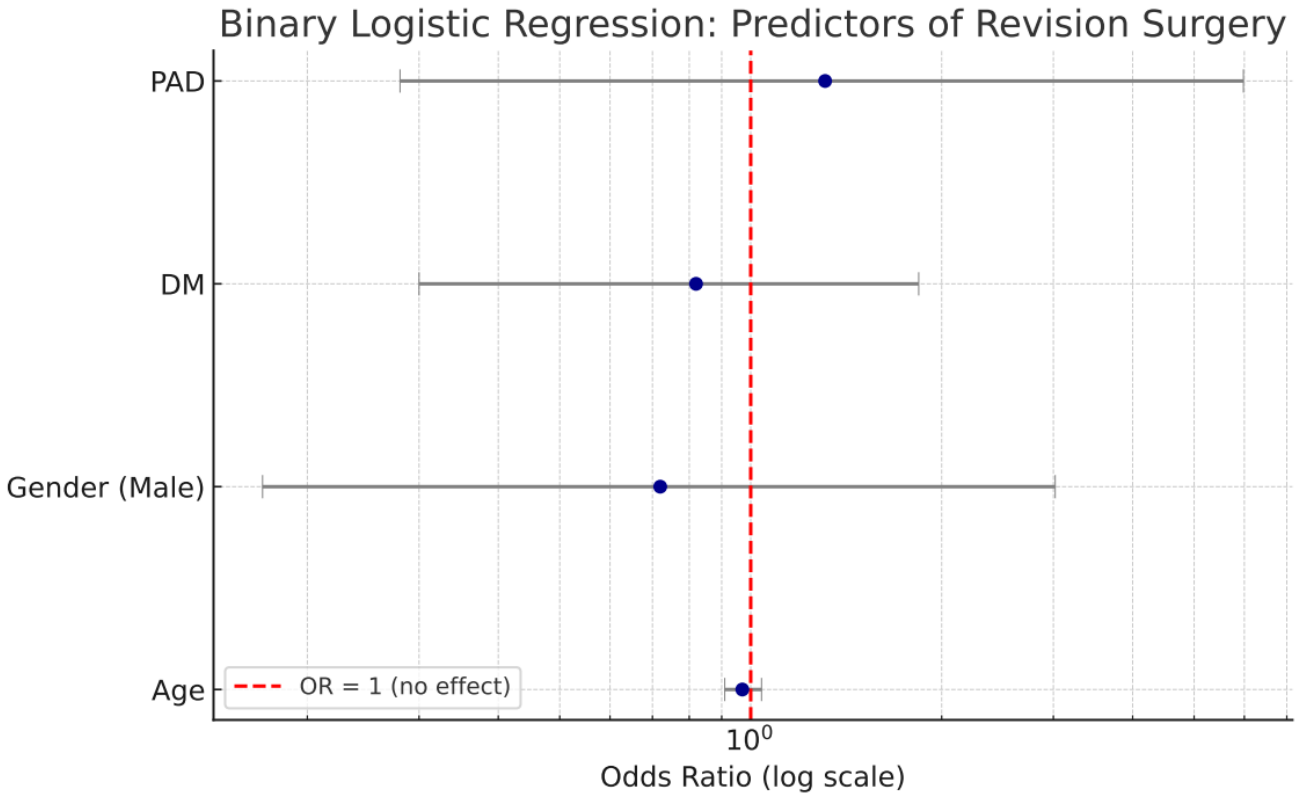

Figure 5: The forest plot illustrates the results of the binary logistic regression analysis evaluating predictors of revision surgery. Each point represents the odds ratio (OR) for a variable, with horizontal lines indicating 95% confidence intervals (CIs). The red dashed vertical line marks the null value (OR = 1), which indicates no effect. All variables—age, gender, diabetes mellitus (DM), and peripheral arterial disease (PAD)—have confidence intervals crossing the line of no effect, confirming that none were statistically significant predictors of revision surgery in this cohort. The model's modest R^2 value and classification accuracy further emphasize the limited predictive influence of these clinical factors.

Conclusion

In this retrospective comparative cohort study of 58 high-risk patients undergoing toe amputation for diabetic foot infection, no significant differences were observed between closure techniques with respect to revision rates, need for repeated revisions, hospital length of stay, or progression to more proximal amputation. Revision rates were high across both groups, with the majority of patients requiring at least one secondary procedure and an average of 2.4 revisions per patient. Logistic regression analysis identified diabetes mellitus type 2 and peripheral arterial disease as independent risk factors for failure of primary amputation, whereas age and sex were not predictive. These findings suggest that in patients with severe metabolic and vascular disease, systemic comorbidities may outweigh local surgical factors in determining outcomes following toe amputation. Careful patient optimization, early vascular assessment and intervention, and individualized surgical planning remain essential. Larger, prospective studies are needed to further clarify the relative contribution of closure technique versus patient-related factors and to identify strategies that may reduce the high burden of revision surgery in this challenging population.

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