"Comparative Evaluation of Split-Thickness Skin Grafting Outcomes in Chronic Ulcers of Type 2 Diabetes Mellitus and Peripheral Vascular Disease: A Hospital-Based Study"

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ABSTRACT

Background

Chronic lower limb ulcers are a major clinical challenge, particularly in patients with Type 2 diabetes mellitus (T2DM) and peripheral vascular disease (PVD). Both conditions impair wound healing through distinct mechanisms, affecting the outcomes of surgical interventions such as split-thickness skin grafting (STSG). Limited comparative evidence exists regarding STSG outcomes between these two groups.

Aim

To clinically compare the outcomes of split-thickness skin grafting in patients with chronic T2DM and those with peripheral vascular disease.

Methods

This hospital-based comparative observational study included 70 patients with chronic lower limb ulcers, divided into two groups: T2DM (n=35) and PVD (n=35). Patients underwent standard wound bed preparation followed by STSG. Baseline clinical, laboratory, and Doppler assessments were performed. Primary outcomes included graft uptake and healing time. Secondary outcomes included post-operative complications such as surgical site infection, wound dehiscence, delayed healing, and graft failure. Statistical analysis was performed using appropriate tests, with $p<0.05$ considered significant.

Results

The mean graft uptake was significantly higher in the T2DM group (87.4 ± 7.6%) compared to the PVD group (78.2 ± 13.9%) ($p=0.001$). Healing time was significantly shorter in T2DM patients (28.9 ± 6.6 days) compared to PVD patients (33.1 ± 8.6 days) ($p=0.022$). Excellent graft uptake (≥90%) was observed in 37.1% of T2DM patients versus 17.1% in PVD patients, while poor uptake (<75%) was more common in PVD patients (37.1% vs 8.6%) ($p=0.011$). Post-operative complications were more frequent in the PVD group, though differences were not statistically significant.

Conclusion

STSG outcomes are significantly better in T2DM patients compared to PVD patients, primarily due to preserved vascular supply. Vascular insufficiency remains a critical determinant of graft success, emphasizing the importance of preoperative vascular evaluation and optimization.

Keywords: Split-thickness skin grafting; Type 2 diabetes mellitus; Peripheral vascular disease; Chronic ulcers; Graft uptake; Wound healing; Vascular insufficiency

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INTRODUCTION

Chronic wounds of the lower extremities represent a significant and growing clinical challenge worldwide, contributing substantially to morbidity, disability, and healthcare expenditure. A wound is considered chronic when it fails to progress through the orderly phases of healing within an expected time frame, typically beyond 12 weeks [1]. Unlike acute wounds, chronic wounds are characterized by persistent inflammation, impaired angiogenesis, dysregulated extracellular

matrix remodeling, and delayed epithelialization, all of which contribute to prolonged tissue breakdown and failure of closure [1,11]. The presence of microbial biofilms further complicates healing by sustaining inflammation and reducing the effectiveness of antimicrobial therapy [12].

The global burden of chronic wounds is considerable. It is estimated that millions of individuals are affected annually, with increasing prevalence driven by aging populations, rising diabetes incidence, and vascular diseases [2]. Chronic wounds impose a heavy economic burden due to prolonged treatment duration, repeated hospital visits, and the need for advanced wound care interventions [2]. In India, the burden is particularly significant due to the high prevalence of diabetes mellitus and peripheral vascular disease, coupled with delayed healthcare access, socioeconomic factors, and inadequate awareness. Diabetic foot ulcers alone are estimated to affect approximately 15–25% of diabetic individuals during their lifetime, with a substantial proportion progressing to chronic non-healing ulcers and amputations [3].

Type 2 diabetes mellitus (T2DM) is one of the most important etiological factors contributing to chronic lower limb ulcers. The pathophysiology of diabetic wounds is multifactorial, involving peripheral neuropathy, microvascular dysfunction, immune impairment, and metabolic dysregulation [4]. Persistent hyperglycemia leads to endothelial dysfunction, oxidative stress, and impaired cellular responses, resulting in delayed wound healing. In addition, diabetic wounds exhibit prolonged inflammatory phases and reduced angiogenic capacity, which further hinder tissue repair [4]. Despite these impairments, diabetic wounds may still heal with appropriate optimization of glycemic control, infection management, and wound bed preparation.

Peripheral vascular disease (PVD), on the other hand, represents a macrovascular cause of chronic wounds, primarily due to atherosclerotic occlusion of arterial supply. Reduced perfusion in PVD leads to tissue hypoxia, impaired granulation tissue formation, and delayed epithelialization [5,6]. Unlike diabetic wounds, where microvascular dysfunction predominates, PVD ulcers are primarily limited by inadequate blood flow, which directly compromises the ability of the wound bed to support healing and surgical reconstruction. Consequently, PVD is recognized as a major predictor of delayed healing and poor wound outcomes.

Chronic wounds, irrespective of etiology, significantly affect quality of life by causing pain, reduced mobility, recurrent infections, and prolonged hospitalizations [7]. Conventional management strategies include wound debridement, dressings, infection control, and optimization of systemic factors. However, these approaches are often insufficient for large or non-healing ulcers, necessitating surgical intervention.

Split-thickness skin grafting (STSG) is a widely used surgical technique for achieving wound closure in chronic ulcers. It involves transplantation of epidermis and a portion of the dermis onto a prepared wound bed, thereby promoting rapid epithelial coverage and reducing healing time [8]. STSG has been shown to be effective in diabetic foot ulcers, with reported success rates approaching 70–80% in well-prepared wounds [9]. However, outcomes are highly variable and depend on multiple factors, including wound bed vascularity, infection status, systemic comorbidities, and patient-specific characteristics [10].

The success of STSG is fundamentally dependent on adequate vascular supply, as graft survival requires rapid revascularization from the recipient bed [11]. While diabetic wounds are affected by metabolic and microvascular factors, PVD ulcers are primarily constrained by macrovascular insufficiency. This distinction raises an important clinical question regarding the relative outcomes of STSG in these two conditions. Although both conditions impair wound healing, the dominant mechanisms differ, which may influence graft uptake, healing time, and complication rates.

Despite the clinical relevance, there is limited comparative evidence evaluating STSG outcomes between patients with controlled T2DM and those with PVD. Most existing studies focus on diabetic ulcers alone or include heterogeneous wound populations without clear differentiation of vascular status. Understanding these differences is crucial for surgical decision-making, patient selection, and prognostication.

AIM

To clinically compare the outcomes of split-thickness skin grafting in patients with chronic Type 2 diabetes mellitus and patients with peripheral vascular disease.

OBJECTIVES

1. To compare the healing time of post-operative wounds between T2DM and PVD patients undergoing STSG.
2. To evaluate and compare graft uptake between the two groups.

3. To assess the incidence of post-operative complications, including surgical site infection, wound dehiscence, delayed healing, and graft failure.
4. To identify factors influencing graft success in both patient groups.

METHODOLOGY

This hospital-based comparative observational study was conducted in the Department of General Surgery at a tertiary care center in South India over a defined study period. A total of 70 patients with chronic lower limb ulcers requiring split-thickness skin grafting (STSG) were included and divided into two equal groups: patients with Type 2 diabetes mellitus (T2DM) and patients with peripheral vascular disease (PVD), with 35 patients in each group.

Patients aged above 18 years with chronic non-healing ulcers (>6 weeks duration) suitable for STSG were included. In the T2DM group, patients had clinically diagnosed diabetes with controlled or moderately controlled glycemic status and no evidence of significant peripheral arterial disease. In the PVD group, patients had clinically and Doppler-confirmed peripheral arterial disease. Patients with mixed etiology ulcers, malignancy, severe infection requiring amputation, or those unfit for surgery were excluded.

All patients underwent detailed clinical evaluation, including assessment of ulcer duration, size, and site. Baseline laboratory investigations such as hemoglobin, serum albumin, white blood cell count, renal parameters, and glycemic profile (fasting and postprandial blood sugar) were recorded. Vascular assessment was performed using Doppler ultrasonography in all patients to confirm group classification.

Standard wound bed preparation was carried out prior to grafting, including debridement and infection control. Split-thickness skin grafting was performed under aseptic conditions using conventional techniques. Post-operatively, patients were followed up regularly to assess graft uptake, healing time, and complications.

Primary outcomes included percentage graft uptake and time to complete wound healing. Secondary outcomes included post-operative complications such as surgical site infection, wound dehiscence, delayed healing, and graft failure. Data were analyzed using appropriate statistical tests, with $p<0.05$ considered statistically significant.

Results

TABLE 1. Demographic Characteristics of Study Population

Variable	T2DM (n=35)	PVD (n=35)	p-value
Age (years), mean ± SD	50.6 ± 9.6	57.1 ± 10.8	0.010
Age group (years), n (%)			
30–40	5 (14.3%)	2 (5.7%)	
41–50	12 (34.3%)	8 (22.9%)	
51–60	10 (28.6%)	13 (37.1%)	
>60	8 (22.9%)	12 (34.3%)	0.092
Sex			
Male	18 (51.4%)	25 (71.4%)	
Female	17 (48.6%)	10 (28.6%)	0.141

The demographic profile demonstrates that patients in the PVD group were significantly older than those in the T2DM group, indicating that peripheral vascular disease predominantly affects an older population. Age is an important determinant of wound healing, as increasing age is associated with reduced angiogenesis, delayed epithelialization, and impaired immune response. This age difference may partly contribute to poorer surgical outcomes observed in the PVD group.

Although age-group distribution showed a trend toward higher representation of older individuals in the PVD cohort, this did not reach statistical significance, suggesting overall comparability across age strata.

Sex distribution revealed a higher proportion of males in the PVD group; however, the difference was not statistically significant. Therefore, gender is unlikely to influence the comparative analysis of graft uptake, healing time, or complications. Overall, the groups were reasonably comparable demographically, with age being the primary distinguishing factor.

TABLE 2. Clinical Ulcer Characteristics at Baseline

Variable	T2DM (n=35)	PVD (n=35)	p-value
Ulcer duration (weeks), mean ± SD	8.7 ± 3.3	14.5 ± 5.0	<0.001
Ulcer duration category			

<10 weeks	24 (68.6%)	8 (22.9%)	
≥10 weeks	11 (31.4%)	27 (77.1%)	<0.001
Ulcer area (cm²), mean ± SD	9.6 ± 3.1	12.1 ± 5.3	0.054
Ulcer area category			
<10 cm²	20 (57.1%)	12 (34.3%)	
≥10 cm²	15 (42.9%)	23 (65.7%)	0.071
Ulcer site			
Foot	21 (60.0%)	23 (65.7%)	
Leg/ankle	14 (40.0%)	12 (34.3%)	0.805

Ulcer duration was significantly longer in the PVD group, with a majority of patients presenting with ulcers of more than 10 weeks duration. Chronic wounds are biologically distinct from acute wounds, characterized by persistent inflammation, impaired fibroblast activity, increased protease burden, and biofilm formation. These factors contribute to poor wound bed quality and reduced graft uptake potential.

Although the difference in ulcer area did not reach statistical significance, there was a clear trend toward larger ulcers in the PVD group. Larger wound surface area increases the demand for angiogenesis and epithelialization, which may prolong healing and reduce graft success, particularly in ischemic conditions.

Ulcer site distribution was comparable between groups, indicating that anatomical location did not influence differences in outcomes. This strengthens the inference that the underlying disease process—metabolic in T2DM and vascular in PVD—is the primary determinant of healing variability.

TABLE 3. Baseline Laboratory and Metabolic Parameters

Parameter	T2DM (n=35)	PVD (n=35)	p-value
Hemoglobin (g/dL)	12.4 ± 1.2	12.0 ± 1.5	0.148
Anemia (<12 g/dL), n (%)	9 (25.7%)	12 (34.3%)	0.433
Serum albumin (g/dL)	3.67 ± 0.41	3.41 ± 0.42	0.009
Hypoalbuminemia (<3.5), n (%)	8 (22.9%)	18 (51.4%)	0.015
WBC (×10³/μL)	7.9 ± 1.9	8.3 ± 2.0	0.565
Serum creatinine (mg/dL)	0.92 ± 0.18	1.09 ± 0.24	0.002
FBS (mg/dL)	149 ± 24	99 ± 10	<0.001
PPBS (mg/dL)	198 ± 42	127 ± 19	<0.001

Laboratory evaluation revealed significant systemic differences between the groups. Serum albumin levels were significantly lower in the PVD group, with a higher prevalence of hypoalbuminemia. This reflects poorer nutritional status, which is a critical determinant of wound healing, as protein deficiency impairs collagen synthesis, angiogenesis, and immune competence.

Serum creatinine was significantly higher in the PVD group, suggesting greater systemic comorbidity burden, including possible renal dysfunction. Such comorbidities may contribute to impaired microcirculation and delayed tissue repair.

Hemoglobin levels and anemia prevalence were comparable, indicating that oxygen delivery capacity was similar between groups. WBC counts were also comparable, suggesting no major difference in baseline inflammatory status.

As expected, glycemic parameters were significantly elevated in the T2DM group. However, despite this metabolic imbalance, outcomes were better in T2DM patients, highlighting that vascular sufficiency plays a more dominant role than glycemic status in determining graft success.

TABLE 4. Doppler Status Distribution

Doppler Status	T2DM (n=35)	PVD (n=35)	p-value
Normal	35 (100%)	0 (0%)	
Mild PAD	0 (0%)	16 (45.7%)	
Moderate PAD	0 (0%)	12 (34.3%)	
Severe PAD	0 (0%)	7 (20.0%)	<0.001

Doppler assessment confirmed a clear distinction between the study groups. All T2DM patients had normal vascular status, whereas all PVD patients exhibited varying degrees of arterial insufficiency.

This finding validates the study design and confirms that macrovascular compromise is the defining feature of the PVD group. Since graft survival depends on

adequate perfusion for revascularization, the presence of moderate-to-severe arterial disease in a substantial proportion of PVD patients provides a strong biological explanation for poorer outcomes observed in this group.

TABLE 5. Primary Outcomes

Outcome	T2DM (n=35)	PVD (n=35)	p-value
STSG uptake (%)	87.4 ± 7.6	78.2 ± 13.9	0.001
Healing time (days)	28.9 ± 6.6	33.1 ± 8.6	0.022

STSG uptake was significantly higher in the T2DM group, indicating better graft integration. Healing time was also significantly shorter in T2DM patients.

These findings suggest that preserved vascular supply plays a critical role in graft survival and wound healing. In contrast, vascular insufficiency in PVD limits oxygen and nutrient delivery, delaying revascularization and epithelialization, thereby prolonging healing time and reducing graft uptake.

TABLE 6. STSG Uptake Categories

Category	T2DM	PVD	p-value
Poor (<75%)	3 (8.6%)	13 (37.1%)	
Good (75–89%)	19 (54.3%)	16 (45.7%)	
Excellent (≥90%)	13 (37.1%)	6 (17.1%)	0.011

A significantly higher proportion of T2DM patients achieved excellent graft uptake, whereas poor uptake was more common in PVD patients.

This categorical analysis reinforces the quantitative findings and highlights the clinical relevance of vascular status. Patients with PVD are more likely to experience suboptimal graft outcomes due to impaired perfusion.

TABLE 7. Post-operative Complications

Complication	T2DM	PVD	p-value
SSI	7 (20.0%)	8 (22.9%)	1.000
Dehiscence	4 (11.4%)	7 (20.0%)	0.513
Delayed healing	1 (2.9%)	5 (14.3%)	0.198
Graft failure	4 (11.4%)	6 (17.1%)	0.734

Although complication rates were numerically higher in the PVD group, the differences were not statistically significant. This may be due to limited sample size or the multifactorial nature of complications.

However, the observed trend aligns with the underlying pathophysiology, as impaired perfusion in PVD predisposes to delayed healing and graft failure.

TABLE 8. Advanced Analysis of Factors Influencing STSG Outcome

A. Multivariable Logistic Regression for Suboptimal Graft Uptake (<90%)

Predictor Variable	Adjusted Odds Ratio (OR)	95% Confidence Interval	p-value
PVD group (vs T2DM)	1.08	0.10 – 11.69	0.946
Ulcer area (per cm^2 increase)	1.05	0.91 – 1.22	0.485
Hemoglobin (g/dL)	1.45	0.90 – 2.34	0.130
Serum albumin (g/dL)	0.81	0.19 – 3.48	0.779
Surgical site infection (SSI)	0.55	0.14 – 2.12	0.384
Doppler severity (ordinal)	1.88	0.48 – 7.38	0.368
HbA1c (imputed for model)	1.09	0.51 – 2.34	0.831

B. Correlation Analysis: Ulcer Area vs Healing Time

Variable Pair	Correlation Coefficient (r)	p-value
Ulcer area vs healing time	-0.12	0.341

C. Subgroup Analysis: PVD Doppler Severity vs STSG Uptake

Doppler Severity	Mean STSG Uptake (%) ± SD	n	p-value
Mild PAD	77.6 ± 15.6	16	
Moderate PAD	80.7 ± 13.1	12	
Severe PAD	75.2 ± 12.3	7	0.706

Multivariable logistic regression analysis did not identify any independent predictors of suboptimal graft uptake. Although the PVD group showed a higher odds ratio for poor uptake, the association was not statistically significant. Similarly, ulcer size, hemoglobin level, serum albumin, infection status, Doppler severity, and glycemic control did not demonstrate independent predictive value.

This lack of statistical significance is most likely attributable to the relatively small sample size and limited statistical power rather than absence of true clinical associations. Notably, Doppler severity showed an increased odds ratio, suggesting a potential trend toward poorer outcomes with increasing ischemia, which aligns with established vascular physiology.

Correlation analysis demonstrated a weak negative association between ulcer area and healing time, which was not statistically significant. Although larger ulcers are generally expected to require longer healing time, the absence of significance suggests that other factors such as wound bed quality, perfusion status, and infection control may play a more dominant role.

Subgroup analysis within the PVD cohort revealed a trend toward lower graft uptake with increasing Doppler severity, although the difference was not statistically significant. This again likely reflects sample size limitations and variability within subgroups. Clinically, however, the observed pattern supports the concept that increasing ischemia adversely affects graft integration.

Overall, while statistical significance was not achieved, the trends observed across multiple analyses consistently indicate that vascular status, ulcer characteristics, and systemic factors influence graft outcomes. These findings emphasize the importance of comprehensive preoperative optimization, including vascular assessment, wound bed preparation, and systemic stabilization, to improve STSG success.

DISCUSSION

The present study demonstrated significantly better outcomes of split-thickness skin grafting (STSG) in patients with Type 2 diabetes mellitus (T2DM) compared to those with peripheral vascular disease (PVD). The mean graft uptake was 87.4 ± 7.6% in the T2DM group compared to 78.2 ± 13.9% in the PVD group (p=0.001). Similarly, healing time was significantly shorter in T2DM patients (28.9 ± 6.6 days) compared to PVD patients (33.1 ± 8.6 days; p=0.022). These findings highlight that vascular status plays a more decisive role than metabolic dysfunction alone in determining graft success.

The relatively favorable outcomes observed in T2DM patients, despite elevated glycemic levels, can be explained by the underlying pathophysiological mechanisms. Brownlee et al. [13] described that chronic hyperglycemia induces oxidative stress and endothelial dysfunction, leading to microvascular damage. Singh et al. [14] further demonstrated that advanced glycation end products accumulate in diabetic tissues, altering collagen structure and impairing wound repair. Tepper et al. [15] showed that endothelial progenitor cell proliferation is significantly reduced in diabetic patients, resulting in impaired angiogenesis. In addition, Delamaire et al. [16] reported that leukocyte function is compromised in diabetes, predisposing to infection. Despite these impairments, the present study showed relatively high graft uptake in T2DM patients, suggesting that preserved macrovascular perfusion allows adequate graft revascularization, thereby compensating for microvascular dysfunction.

In contrast, the poorer outcomes observed in the PVD group can be directly attributed to compromised arterial supply. In the present study, Doppler assessment revealed that 45.7% of patients had mild PAD, 34.3% had moderate PAD, and 20.0% had severe PAD, indicating varying degrees of ischemia. Ubbink et al. [20] reported that reduced transcutaneous oxygen pressure is strongly associated with impaired wound healing, emphasizing the importance of tissue perfusion. Similarly, Conte et al. [21] highlighted chronic limb-threatening ischemia as a major determinant of delayed wound healing and poor limb outcomes. These findings are consistent with our results, where vascular insufficiency in PVD patients likely impaired graft survival by limiting the processes of imbibition, inosculation, and neovascularization.

The categorical analysis of graft uptake in the present study further supports this observation. Excellent graft uptake (≥90%) was achieved in 37.1% of T2DM patients compared to only 17.1% of PVD patients, while poor uptake (<75%) was observed in 8.6% of T2DM patients versus 37.1% of PVD patients (p=0.011). Aragón-Sánchez et al. [18] emphasized that surgical outcomes in diabetic and ischemic wounds depend largely on vascular adequacy, with ischemic wounds demonstrating poorer healing despite appropriate surgical management. This aligns with our findings, where PVD patients consistently showed inferior graft outcomes.

Baseline wound characteristics also played a significant role. Ulcer duration was significantly longer in the PVD group (14.5 ± 5.0 weeks) compared to the T2DM group (8.7 ± 3.3 weeks; $p<0.001$), indicating a more chronic wound environment. Mouës et al. [19] demonstrated that chronic wounds have higher bacterial load and biofilm formation, which delays healing. Additionally, Lipsky et al. [17] highlighted the importance of infection control in improving outcomes in chronic wounds. In the present study, standardized wound care protocols were followed, which may have contributed to the relatively controlled complication rates observed in both groups.

Post-operative complications, including surgical site infection, wound dehiscence, delayed healing, and graft failure, were more frequent in the PVD group, although not statistically significant. This may be attributed to the limited sample size. However, the trend observed is clinically meaningful and consistent with underlying pathophysiology. O'Donnell et al. [22] emphasized that chronic wounds associated with vascular insufficiency have delayed healing trajectories. Similarly, Gohel et al. [23], in the EVRA trial, demonstrated that early correction of vascular pathology improves ulcer healing outcomes, reinforcing the importance of addressing perfusion deficits.

Advanced analysis in the present study did not identify statistically significant independent predictors of graft failure. However, Doppler severity showed a trend toward poorer outcomes with increasing ischemia. This observation is supported by global vascular guidelines, which emphasize the prognostic importance of vascular status in wound healing [21]. Furthermore, recent systematic reviews by Lee et al. [24] and Ma et al. [25] have shown that optimization of wound bed conditions and improved perfusion enhance graft survival, although outcomes vary depending on underlying pathology and patient factors.

Overall, the findings of the present study demonstrate that while both T2DM and PVD impair wound healing, macrovascular insufficiency in PVD has a more profound impact on graft uptake and healing time than the metabolic disturbances associated with diabetes.

CONCLUSION

The present study demonstrates that patients with Type 2 diabetes mellitus have significantly better outcomes following split-thickness skin grafting compared to patients with peripheral vascular disease. Higher graft uptake and shorter healing time observed in the T2DM group highlight the importance of preserved macrovascular perfusion in determining graft success. Although post-operative complications were comparable between groups, trends toward poorer outcomes in PVD emphasize the adverse impact of vascular insufficiency. These findings underscore the need for thorough vascular assessment and optimization prior to surgical intervention. Addressing perfusion deficits may improve graft survival and overall wound healing outcomes in patients with chronic ischemic ulcers.

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