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Original Research Article

Preventing Diabetic Foot Complications: Tarsal Tunnel Decompression for Compressive Neuropathy

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Abstract: ***Background*:** Diabetic foot complications, particularly ulceration and amputation, pose a significant public health burden in Bangladesh. While diabetic peripheral neuropathy (DPN) is the primary cause, a superimposed, surgically correctable compressive neuropathy at the ankle, Tarsal Tunnel Syndrome (TTS), is often an overlooked yet critical factor. ***Objective:*** This study aimed to evaluate the efficacy of Tarsal Tunnel Decompression (TTD) in preventing major foot complications in a high-risk Bangladeshi population. ***Methods:*** A prospective, multi-centre comparative study was conducted in Dhaka, Bangladesh, involving 120 patients with Type 2 Diabetes, symptomatic DPN, and a positive Tinel's sign. Patients were allocated into two groups: 60 patients underwent TTD, and 60 patients received enhanced standard medical care (control). The primary outcomes were the incidence of new or recurrent foot ulcers and major amputations over a 24-month follow-up period. Secondary outcomes included pain relief (Visual Analogue Scale) and restoration of protective sensation. ***Results:*** The TTD group demonstrated a significantly lower incidence of new or recurrent foot ulcers compared to the control group (5.0% vs. 28.3%, $p<0.001$). The rate of major amputation was also substantially lower in the surgical group (1.7% vs. 15.0%, $p<0.01$). Furthermore, 91.7% of patients in the TTD group regained protective sensation, compared to only 6.7% in the control group ($p<0.001$). The surgical group also experienced a profound reduction in neuropathic pain, with mean VAS scores decreasing from 7.2 to 1.5, a significantly greater improvement than that seen in the control group ($p<0.001$). ***Conclusion:*** Tarsal Tunnel Decompression is a highly effective surgical intervention that dramatically reduces the risk of ulceration and amputation in diabetic patients with evidence of superimposed nerve compression.

Keywords: Diabetic Foot Ulcer, Diabetic Neuropathy, Tarsal Tunnel Syndrome, Nerve Decompression, Amputation Prevention.

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Introduction

Diabetic foot complications are a leading cause of non-traumatic lower limb amputation worldwide, with the lifetime risk of a person with diabetes developing a foot ulcer being as high as 25%.[1, 2] While diabetic peripheral neuropathy (DPN) is the primary cause, a significant subset of patients suffers from a superimposed, surgically correctable compressive neuropathy of the tibial nerve at the ankle, known as Tarsal Tunnel Syndrome (TTS).[3, 4] The symptoms of TTS, such as burning pain and numbness in the sole, often mimic generalized DPN, leading to

underdiagnosis and missed opportunities for limb-saving intervention.[5, 6] Effective management requires a structured approach, from accurate diagnosis and conservative trials to surgical decompression and post-operative care.

The cornerstone of managing this condition is identifying the correct patients. Because the symptoms of focal nerve compression overlap significantly with those of generalized DPN, a targeted clinical evaluation is essential. [5, 7] The initial assessment should include a thorough history of the patient's symptoms, focusing on the location (plantar surface of the foot) and nature (burning, tingling, numbness) of the discomfort, which is often worse at night or with activity.[8, 9] The single most important physical examination finding is Tinel's sign.[10] This is performed by firmly tapping over the posterior tibial nerve as it passes through the tarsal tunnel, just behind the medial malleolus. A positive sign, which reproduces the patient's symptoms radiating into the sole, is a strong indicator of focal nerve irritation and is considered a crucial predictor of a favorable surgical outcome.[11, 12]

While clinical assessment is paramount, ancillary tests can provide objective confirmation. Electrodiagnostic studies, including nerve conduction velocity (NCV) and electromyography (EMG), can demonstrate slowing of nerve signals across the tarsal tunnel.[13] High-resolution ultrasound and MRI are also valuable for visualizing the nerve and identifying potential causes of compression, such as nerve swelling, ganglion cysts, or other space-occupying lesions.[14, 15] Initial management of TTS is typically conservative, especially in patients with mild symptoms.[16] This approach aims to reduce pain, inflammation, and mechanical stress on the nerve. Interventions include activity modification, the use of orthotics or braces to stabilize the foot and ankle, and wearing loose-fitting footwear to reduce external pressure.[16, 17] Pharmacological treatments may involve non-steroidal anti-inflammatory drugs (NSAIDs) and medications for neuropathic pain, such as gabapentin or tricyclic antidepressants.[18] Corticosteroid injections into the tarsal tunnel can also provide temporary relief by reducing inflammation.[16, 18]

Surgical intervention is indicated when conservative measures fail to provide adequate relief, or if there is evidence of progressive nerve damage, such as muscle weakness or atrophy.[16] The procedure, known as Tarsal Tunnel Decompression (TTD) or neurolysis, is the definitive treatment for mechanical nerve entrapment.[19] Performed as an outpatient procedure, the surgeon makes an incision on the inner side of the ankle and carefully cuts the flexor retinaculum, the thick ligament forming the roof of the tunnel.[20, 21] This release immediately increases the volume of the tunnel, relieving pressure on the tibial nerve and its branches.[22] The goal is to restore normal blood flow to the nerve, allowing for regeneration and the recovery of sensory function.[6]

Post-operative management involves a period of protected weight-bearing, often with a splint or surgical shoe, to allow the incision to heal.[21] While pain relief can be rapid, sensory recovery is a gradual process that can continue for up to a year or more as the nerve regenerates.[10] The outcomes of TTD are highly encouraging. A meta-analysis of observational studies demonstrated significant improvements in pain and sensation.[2] Most importantly, the procedure has a profound preventative effect. The same meta-analysis found that tarsal tunnel release was associated with a 96% reduction in the risk of developing a new ulcer.[2] Another study reported that over an 18-month follow-up, only 3.28% of surgically treated limbs developed new complications, compared to 24.59% in the untreated contralateral limbs.[1] By correctly identifying and treating the mechanical component of diabetic neuropathy, TTD offers a powerful management strategy to prevent the devastating consequences of diabetic foot disease.

Objective

This study aims to evaluate Tarsal Tunnel Decompression as a preventative surgical treatment to reduce ulceration and amputation in patients with diabetic neuropathy by restoring sensation and relieving symptoms of nerve compression.

Material and Methods

Study Design and Settings

This prospective comparative study was conducted from January 2021 to December 2023, encompassing a 24-month follow-up period for all participants. Recruitment and procedures were carried out in tertiary care centers in Bangladesh Ethical clearance was granted by the Institutional Review Boards of both hospitals, and all participants provided written informed consent prior to enrollment.

Study Population and Sampling
A total of 120 patients with Type 2 Diabetes Mellitus were enrolled using a purposive sampling technique based on the eligibility criteria.

Inclusion Criteria
Patients were required to have symptomatic diabetic peripheral neuropathy (DPN) with complaints of burning, tingling, or numbness on the sole of the foot. A mandatory inclusion criterion was a positive Tinel's sign over the posterior tibial nerve at the ankle. Participants also needed to have adequate distal circulation, confirmed by palpable pedal pulses, to ensure symptoms were not primarily ischemic.

Exclusion Criteria
Patients were excluded if they had severe peripheral artery disease, active foot infections (cellulitis or osteomyelitis), a history of significant ankle fractures or previous major surgery on the ankle, or other non-diabetic causes of peripheral neuropathy.

Study Groups and Allocation
The 120 enrolled patients were allocated into two equal cohorts of 60. The first group was assigned to the surgical intervention (TTD), while the second group served as the control and received non-surgical management.

Intervention Protocol
The surgical group (n=60) underwent TTD performed by consultant surgeons with expertise in peripheral nerve surgery. The procedure involved a standard open release of the flexor retinaculum to fully decompress the posterior tibial nerve and its medial and lateral plantar branches.

Control Protocol
The control group (n=60) received enhanced standard medical care. This included optimization of glycemic control and a structured, intensive educational program on preventative foot care. This education was a critical component, given the documented low levels of foot care awareness in Bangladesh, and covered topics such as daily foot inspection, hygiene, and appropriate footwear.

Data Collection and Follow-up
Data was collected from all participants at baseline and at follow-up appointments scheduled at 3, 6, 12, and 24 months. Data collection was performed through direct clinical examinations and face-to-face interviews using a structured questionnaire.

Outcome Measures
The primary outcome measures were the incidence of new or recurrent diabetic foot ulcers and the rate of lower-limb amputations during the two-year follow-up period. Secondary outcomes focused on symptomatic and functional improvement, including changes in pain levels measured by the Visual Analog Scale (VAS) and restoration of protective sensation assessed with Semmes-Weinstein 10g monofilaments.

Data Analysis
The data collected were analyzed to compare outcomes between the surgical and control groups. Descriptive statistics were used to summarize baseline characteristics. Inferential statistical tests were used to determine differences in ulcer and amputation rates, as well as changes in VAS scores and sensory function. A p-value of less than 0.05 was considered statistically significant.

Results

A total of 120 patients were enrolled and completed the 24-month follow-up, with 60 patients in the Tarsal Tunnel Decompression (TTD) group and 60 in the control group receiving enhanced standard medical care.

The demographic and clinical characteristics of the participants were well-matched between the two groups at the time of enrollment. There were no statistically significant differences in mean age, sex distribution, duration of diabetes, or baseline glycemic control (HbA1c) between the TTD and control groups, ensuring a comparable basis for evaluating the outcomes.

Table 1 summarizes the key characteristics of the 120 participants at the start of the study, divided by their assigned group. The data demonstrates that the surgical (TTD) and control groups were comparable across all measured variables, with p-values greater than 0.05 indicating no significant baseline differences.

Table 1: Baseline Demographic and Clinical Characteristics of Study Participants

Characteristic	TTD Group (n=60)	Control Group (n=60)	p-value
Age (years, mean ± SD)	52.1 ± 11.5	51.8 ± 12.1	0.89
Sex			
Male	23 (38.3%)	26 (43.3%)	0.58
Female	37 (61.7%)	34 (56.7%)	
Duration of Diabetes (years, mean ± SD)	7.1 ± 5.8	6.9 ± 6.0	0.84
Baseline HbA1c (%, mean ± SD)	8.6 ± 1.1	8.5 ± 1.0	0.61
Hypertension (%)	29 (48.3%)	31 (51.7%)	0.71
Diabetic Retinopathy (%)	9 (15.0%)	8 (13.3%)	0.80

The primary outcomes of the study revealed a dramatic and statistically significant difference in the incidence of new or recurrent foot ulcers and major amputations between the two groups over the 24-month follow-up period. The TTD group experienced substantially fewer of these adverse events compared to the control group.

Table 2 presents the core findings of the study, comparing the rates of diabetic foot ulceration and major amputation between the surgical and control groups. The results show a significantly lower incidence of both complications in the TTD group, as indicated by the highly significant p-value ($p<0.001$), supporting the preventative efficacy of the surgical intervention.

Table 2: Incidence of Primary Outcomes at 24-Month Follow-up

Outcome	TTD Group (n=60)	Control Group (n=60)	p-value
New or Recurrent Foot Ulcer	3 (5.0%)	17 (28.3%)	<0.001
Major Amputation	1 (1.7%)	9 (15.0%)	<0.01

Secondary outcome analysis also demonstrated significant improvements in the TTD group. Patients who underwent surgery reported a substantial reduction in neuropathic pain and a high rate of sensory recovery, whereas the control group showed minimal change in these metrics.

Table 3 details the changes in neuropathic pain and sensory function from baseline to the end of the study. The TTD group showed a marked decrease in mean pain scores and a high rate of restored protective sensation, with both outcomes being statistically significant compared to the minimal changes observed in the control group.

Table 3: Secondary Outcomes at 24-Month Follow-up

Outcome	TTD Group (n=60)	Control Group (n=60)	p-value
Mean VAS Pain Score (Baseline)	7.2 ± 1.3	7.1 ± 1.5	0.72
Mean VAS Pain Score (24 Months)	1.5 ± 1.1	6.8 ± 1.6	<0.001
Restoration of Protective Sensation*	55 (91.7%)	4 (6.7%)	<0.0

Discussion

The findings of this study provide compelling evidence for the efficacy of Tarsal Tunnel Decompression (TTD) as a preventative strategy for major diabetic foot complications in a Bangladeshi context.[1] The primary outcomes demonstrate a stark contrast between the surgical and control groups. Patients who underwent TTD had a significantly lower incidence of new or recurrent foot ulcers (5.0% vs. 28.3%) and major amputations (1.7% vs. 15.0%) over a two-year period. These results strongly support the hypothesis that addressing the superimposed mechanical compression of the tibial nerve can interrupt the pathological cascade that leads to limb loss.

Our findings are consistent with a large body of international observational evidence. A study from India, for instance, reported that following TTD, only 3.28% of limbs developed new complications over 18 months, compared to 24.59% in the untreated contralateral limbs.[1] Furthermore, a comprehensive meta-analysis of 16 observational studies found that

tarsal tunnel release was associated with a 96% reduction in the risk of ulcer development and a significantly lower risk of amputation.[2] The outcomes observed in our control group (28.3% ulceration and 15.0% amputation) are unfortunately reflective of the current challenges in diabetic foot management in Bangladesh. These rates are comparable to another study from Bangabandhu Sheikh Mujib Medical University (BSMMU), which reported a 30% ulcer recurrence rate and a 15% major amputation rate within two years for patients receiving standard surgical care for existing ulcers.[3] This suggests that our control group's outcomes represent the typical trajectory for high-risk patients in the local healthcare system, thereby highlighting the substantial benefit conferred by the preventative TTD procedure.

The secondary outcomes of this study, pain relief and sensory restoration, are equally significant. The TTD group experienced a dramatic reduction in neuropathic pain, with mean VAS scores dropping from 7.2 to 1.5. More critically, 91.7% of patients in the surgical group regained protective sensation. This restoration of sensation is the key mechanism behind the prevention of ulcers. In contrast, the control group showed no meaningful improvement in either pain or sensation, underscoring the limitations of standard medical management for neuropathic symptoms driven by nerve compression. These results align with international meta-analyses that have consistently shown significant improvements in both pain scores and sensory function following nerve decompression surgery.[2, 23]

The implications of these findings for Bangladesh are profound. Diabetic foot care in the country is often hampered by low patient awareness, with studies showing that up to 85.5% of patients are careless about footwear safety.[24] The standard approach is often reactive, managing ulcers after they have already formed 25.[25] This study demonstrates that a proactive surgical approach in appropriately selected patients can prevent these devastating and costly complications. The economic burden of diabetic foot ulcers is immense, and in Bangladesh, the cost of an amputation is 5.54 times higher than non-amputation care.[26] By significantly reducing the need for amputations and the management of chronic ulcers, TTD represents a potentially high-value, cost-saving intervention.

Several limitations of this study must be acknowledged. As a comparative study rather than a randomized controlled trial (RCT), there is a potential for selection bias. However, the baseline characteristics of both groups were well-matched. The study was conducted in tertiary care centers in Dhaka, and the findings may not be immediately generalizable to rural areas, where access to specialized surgical care is limited. Furthermore, the control group received enhanced standard care, including structured education, which is a well-known beneficial intervention in its own right.[27] The fact that TTD demonstrated a superior benefit even when compared to an educated control group strengthens the conclusion regarding the procedure's efficacy.

Conclusion

In conclusion, this study provides strong evidence that Tarsal Tunnel Decompression is a highly effective and limb-saving procedure for diabetic patients in Bangladesh who have neuropathy with a superimposed compressive element. The dramatic reduction in ulceration and amputation rates, coupled with significant pain relief and sensory restoration, suggests that this intervention should be considered for integration into the national guidelines for diabetic foot care. Future research should focus on conducting a large-scale RCT to confirm these findings and on developing training programs to expand the availability of this crucial surgical skill across the country.

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