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Original Research Article

Sensate medial plantar flap for heel reconstruction: a prospective observational study of functional outcomes and complications

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ABSTRACT

Background: Reconstruction of weight-bearing heel defects is challenging because of the heel pad's unique biomechanical properties. The medial plantar flap provides durable plantar-like tissue with potential for sensory restoration. The aim is to evaluate clinical outcomes, complications, sensory recovery, ulcer recurrence, and functional performance following medial plantar flap reconstruction.

Methods: This prospective observational study included 30 patients undergoing medial plantar fasciocutaneous flap reconstruction at S.C.B. Medical College and Hospital, Cuttack, Odisha, India, from August 2022 to October 2024. Donor sites were covered with split-thickness skin grafts. Flap viability, complications, sensory recovery, ulcer recurrence, walking stability, and return to routine activities were assessed.

Results: The mean age was 49.3 years, with 21 males and 9 females. Neuropathic ulcers accounted for 56.6% of defects, followed by malignancy (23.3%) and road traffic accidents (16.6%). Mean operative duration and hospital stay were 110 minutes and 11 days, respectively. Most patients demonstrated improved protective sensation. Ulcer recurrence occurred in 3.3%. Walking stability was satisfactory in 90% and 93.3% of patients at six months and one year, respectively. Mean return to routine activities was 45 days.

Conclusions: The sensate medial plantar flap provides durable heel coverage with satisfactory sensory and functional outcomes. Appropriate patient selection, vascular preservation, rehabilitation, and long-term follow-up are essential.

Keywords: Medial plantar flap, Heel reconstruction, Sensate flap, Fasciocutaneous flap, Plantar ulcer, Functional outcome.

INTRODUCTION

The heel is a critical weight-bearing component of the foot and plays an essential role in shock absorption, postural stability, and normal gait. The heel pad, situated beneath the calcaneus, consists of closely packed adipose tissue partitioned by dense collagenous fibrous septa. These septa organize the fat into relatively confined compartments, allowing the heel pad to resist deformation and withstand repetitive compressive and shear forces during ambulation. Through its viscoelastic properties, the

heel pad dissipates and recovers a proportion of the mechanical energy generated during walking, thereby protecting the underlying calcaneus.

Soft-tissue defects of the heel may result from trauma, chronic neuropathic ulceration, infection, burns, or tumour excision. Reconstruction is particularly challenging when the defect involves the weight-bearing surface, where durable coverage, resistance to shear, and protective sensation are desirable. Tissue from non-plantar regions may provide adequate wound coverage but may not reproduce the specialized mechanical characteristics of native plantar skin and subcutaneous tissue. Consequently, restoration of a functional weight-bearing surface remains an important objective of heel reconstruction.[1,2]

The medial plantar artery flap, also known as the instep flap, is a valuable option for reconstructing selected heel defects. It provides tissue from the non-weight-bearing instep, which shares important structural characteristics with the plantar heel. When appropriately designed and harvested, the flap can provide durable coverage and may facilitate protective sensation through preservation of an appropriate cutaneous nerve branch.[3,4] Assessment of the posterior tibial arterial system and medial plantar vascular supply is essential before undertaking the procedure.

Shanahan and Gingrass first described the medial plantar sensory flap for coverage of heel defects in 1979.[5] Their original technique incorporated the abductor hallucis muscle. Subsequently, Harrison and Morgan described an island fasciocutaneous modification based on the vascular supply arising in the interval between the abductor hallucis and flexor digitorum brevis muscles.[6] These developments established the medial plantar flap as an important local reconstructive option for plantar defects.

The flap offers several advantages, including replacement of plantar tissue with tissue of similar characteristics, the potential for sensate reconstruction, relatively limited donor-site morbidity, and avoidance of microvascular anastomosis. However, its use is constrained by the size and location of the defect, the availability of an intact instep donor site, and the integrity of the posterior tibial and medial plantar vascular systems. Extensive defects, significant vascular insufficiency, and trauma involving the donor site may necessitate alternative regional or free-tissue transfer techniques.[7,8]

Although free flaps have expanded the reconstructive options available for complex heel defects, their use requires microsurgical expertise, appropriate infrastructure, and careful postoperative monitoring 9. In selected patients, a pedicled medial plantar flap offers a less complex alternative while preserving important functional characteristics of plantar tissue.

The present study was undertaken to evaluate the clinical outcomes of medial plantar flap reconstruction for heel defects, with particular emphasis on flap-related complications, sensory recovery, recurrent ulceration, walking stability, and return to routine activities.

METHODS

Study design and setting

This prospective observational study was conducted from August 2022 to October 2024 in the Department of Plastic and Reconstructive Surgery, in collaboration with the Departments of Orthopaedics, General Surgery, and Neurosurgery, at AHRCC, S.C.B. Medical College and Hospital, Cuttack, Odisha, India.

A total of 30 patients with soft-tissue defects involving the heel were included. All patients underwent reconstruction using a medial plantar fasciocutaneous flap, according to the operative protocol.

Eligibility criteria

Inclusion criteria

Inclusion criteria include: soft-tissue defects of the heel following trauma; heel defects associated with neurological impairment, including spinal cord injury and leprosy; heel defects associated with diabetic neuropathy or other neuropathic ulceration; and heel defects following excision of malignancy.

Exclusion criteria

Exclusion criteria include: previous surgery for the same heel defect; tibial nerve lesions or injury involving the plantar donor site; peripheral vascular disease; and poorly controlled diabetes mellitus.

Patients with extensive lower-limb trauma involving the potential vascular pedicle, significant injury around the malleoli, or an unsuitable donor site were also excluded from medial plantar flap reconstruction.

Preoperative assessment

A detailed clinical history and examination were performed for each patient, and the findings were documented using a standardized proforma. The assessment included the aetiology, size, location and depth of the defect; the condition of the surrounding tissues; the integrity of the instep donor site; and the neurological and vascular status of the affected foot.

Routine investigations included complete blood count, random blood glucose, renal function tests, serum electrolytes, HIV screening, hepatitis B surface antigen testing, chest radiography and electrocardiography, as clinically indicated.

Local radiographs were obtained when required. Handheld Doppler assessment was performed to evaluate the

posterior tibial and medial plantar arterial circulation and to identify relevant peroneal perforators where necessary. Wound swab or pus cultures were obtained when infection was suspected.

Flap selection and preoperative planning

Flap planning was based on the dimensions and location of the defect, the configuration of the foot arch, the quality of the instep skin, the condition of the tissues around the medial and lateral malleoli, and the sensory status of the foot. An intact donor site and adequate arterial inflow were considered essential.

A footprint was obtained on plain paper to delineate the weight-bearing and non-weight-bearing portions of the plantar surface. The flap was planned within the non-weight-bearing instep, with its centre positioned over the expected course of the cutaneous perforators near the lateral border of the abductor hallucis muscle. Surface landmarks were established using the medial plantar anatomical axis and the medial border of the plantar aponeurosis.

The flap dimensions were determined by measuring the defect and planning the transfer in reverse. Final dimensions were confirmed intraoperatively. In the study protocol, the medial plantar island flap was used for selected defects measuring approximately 6–8 cm, provided that the instep was intact and the posterior tibial–medial plantar arterial system was patent.

Operative technique

The procedure was performed under spinal or epidural anaesthesia. After exsanguination of the extremity, a pneumatic tourniquet was applied to facilitate dissection in a relatively bloodless field. The medial margin of the planned skin paddle was incised, and the dissection was carried through the fascia overlying the abductor hallucis muscle. Dissection proceeded along the muscle until the septum between the abductor hallucis and flexor digitorum brevis muscles was identified. The septum was preserved and followed into the deeper plane towards the metatarsal region.

The abductor hallucis muscle was retracted medially to expose the medial plantar neurovascular bundle, which was identified near the proximal portion of the intermuscular septum. The proximal dissection was extended towards the division of the posterior tibial vessels, with division of relevant muscular attachments and vascular branches as necessary to obtain adequate pedicle length. The pedicle length was approximately 4–5 cm in the described technique.

The cutaneous nerve branch supplying the flap was preserved and dissected appropriately to facilitate sensate reconstruction when anatomically feasible. The flap was then transferred into the heel defect without undue tension or kinking of the pedicle and secured with sutures. A suction drain was used according to intraoperative requirements.

The donor-site defect was covered with a split-thickness skin graft. The limb was immobilized using a plaster-of-Paris slab for seven days. Weight-bearing was deferred until approximately four weeks after surgery, subject to wound healing and clinical assessment.

Postoperative care and follow-up

Patients were monitored for early postoperative complications, including hematoma, seroma, edema, venous congestion, partial or complete flap necrosis, and donor-site graft loss. The duration of hospitalization and the time required to resume routine activities were recorded. Follow-up assessments were scheduled monthly during the first three months, every three months during the subsequent six months, and annually thereafter where feasible.

Outcomes assessed during follow-up included: flap viability and wound healing; recurrent ulceration over the flap, at the flap interface, or at a new site; donor-site pain, tenderness, and graft-related complications; sensory recovery, including protective sensation, temperature discrimination, and static two-point discrimination; sensory changes in the foot distal to the donor site; walking stability and return to routine activities; and requirement for protective or customized footwear.

Sensory testing was performed using a disposable pin for pain perception, warm and cold stimuli for temperature discrimination, and static two-point discrimination testing.

Outcome measures

The primary outcomes were flap survival and postoperative complications. Secondary outcomes included sensory recovery, recurrent ulceration, walking stability, duration of hospital stay, and time to return to routine activities.

Statistical analysis

The study findings were summarized using descriptive statistics. Continuous variables were reported as means where available, while categorical variables were expressed as frequencies and percentages. No comparative statistical analysis was documented in the available study information.

Ethical considerations

The institutional ethics committee approval number and date, informed-consent details, and procedures for maintaining patient confidentiality should be included in the final manuscript. These details require confirmation from the investigators.

RESULTS

Demographic characteristics

Thirty patients with heel defects underwent reconstruction during the study period. The mean age was 49.3 years. Nineteen patients (63.3%) belonged to the older age category described in the original dataset, while younger patients, particularly those below 30 years of age, predominantly presented with traumatic defects.

There were 21 male patients (70%) and 9 female patients (30%), giving a male-to-female ratio of 2.3:1. Although men constituted the majority of the study population, malignancy-associated defects were reported more frequently among women in the relevant subgroup.

Table 1: Demographic and aetiological characteristics of the study population.

Characteristics	No. of cases	Percentage (%)
Age (in years)		
0-10	0	0
11-20	0	0
21-30	6	20
31-40	2	6.6
41-50	3	10
51-60	11	36.6
More than 60	8	26.6
Total	30	100
Sex		
Male	21	70
Female	9	30
Total	30	100

Aetiology of heel defects

Neuropathic ulceration was the most common cause of heel defects, accounting for 56.6% of cases. The principal underlying conditions included diabetic neuropathy and leprosy. A smaller proportion of patients had defects associated with spinal cord injury or other neurological disorders.

Malignancy accounted for 23.3% of cases, while road traffic accidents accounted for 16.6%. These findings indicate that neuropathic tissue loss represented the largest clinical indication for reconstruction in this series.

Operative characteristics

The mean operative duration for medial plantar flap reconstruction was approximately 110 minutes. The operative time reflected the requirements of careful neurovascular dissection, identification of the pedicle, and preservation of the nerve supply intended to facilitate sensate reconstruction.

Split-thickness skin grafting was used to cover the donor-site defect in all cases, according to the study record. The mean duration of hospital stay following reconstruction was 11 days.

Table 2: Aetiology of heel defects.

Underlying Pathology	No. of cases	Percentage (%)
Post traumatic raw area/defect	5	16.6
Neuropathic ulceration	17	56.6
Malignancy	7	23.3
Unstable scar	1	3.3
Total	30	100

Table 3: Operative characteristics.

Location of the defect	Number	Percentage (%)
Posterior heel	11	36.6
Anterior heel	19	63.6

Table 4: Postoperative complications.

Flap problem	Medial plantar flap (% cases)	Percentage (%)
Venous congestion	2	6.6
Graft loss	1	3.3
Hematoma	4	13.3
Partial flap necrosis	1	3.3

Table 5: Sensory outcomes.

Sensation	6 months follow-up (% of cases)	1 year follow-up (% of cases)
Sharp pain	43.3	73.3
Temperature Warm	50	73.3
Temperature Cold	56.6	76.6
Static two point discrimination	53.3	63.3

Postoperative complications

The reported overall complication rate was 27.6%. Hematoma was the most frequently reported early postoperative complication, occurring in 13.3% of patients. Venous congestion was reported in 6.6%, while partial flap necrosis and donor-site graft loss were each reported in 3.3%.

These findings highlight the importance of meticulous haemostasis, adequate venous drainage, avoidance of pedicle compression, and careful postoperative surveillance.

Table 6: Recurrent ulceration.

Site	Medial plantar flap	Percentage (%)
No ulceration	29	96.6
interface	1	3.3
New site	0	0

Sensory outcomes

Sensory assessment was performed during follow-up, particularly between six months and one year after reconstruction. Testing included pain perception, temperature discrimination, and static two-point discrimination.

Protective sensation and static two-point discrimination reportedly improved in most patients. Sensory function was maintained during longer-term follow-up in the majority of cases. Patients without satisfactory recovery of protective sensation were advised to continue offloading measures and use appropriate protective footwear.

Recurrent ulceration

At approximately one year of follow-up, recurrent ulceration at the flap interface was reported in 3.3% of patients. The supplied results reported no ulceration directly over the flap and no new ulceration sites in the medial plantar flap group during the stated follow-up period.

The study also reported a higher incidence of new-site ulceration among patients with neuropathy overall than among patients without neuropathy, at 34.7% and 5.4%, respectively. These findings require clarification regarding their denominators and the population in which they were measured.

Walking stability and return to routine activities

At six months, 90% of patients were reported to have good walking stability, while the remainder reported average or poor stability. By one year, the proportion reporting good stability increased to 93.3%.

The mean time to return to routine activities, defined as independent walking at approximately normal speed with or without protective footwear, was approximately 45 days.

Use of protective footwear

The supplied data indicated that 13.3% of patients required additional protective footwear during the postoperative period extending up to six months, decreasing to 6.6% at one year. Appropriate footwear and offloading remain important components of postoperative care, particularly in patients with persistent neuropathy.

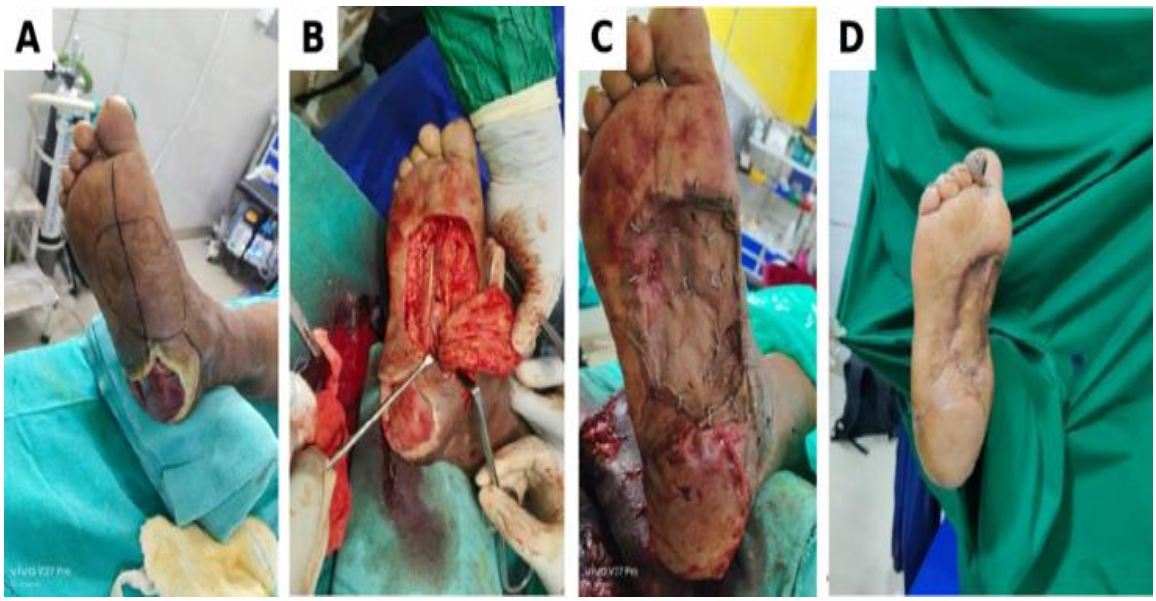


Figure 1: Case 1 diabetic neuropathic heel defect; (A) Preoperative; (B) Intraoperative; (C) Postoperative; (D) Follow-up.



Figure 2 (A-E): Case 2 leprosy heel defect.

DISCUSSION

Reconstruction of heel defects requires more than restoration of soft-tissue coverage. The reconstructed surface must withstand repetitive loading and shear, protect the underlying calcaneus, and, where possible, provide protective sensation. The medial plantar flap is particularly suited to selected defects because it transfers tissue from the non-weight-bearing instep, offering structural characteristics similar to those of the plantar heel

In the present series of 30 patients, neuropathic ulceration was the most common aetiology, followed by malignancy and traumatic injury. This distribution reflects the reconstructive burden associated with loss of protective sensation, chronic pressure, and tissue destruction in patients with diabetes, leprosy, and neurological disorders. The predominance of male patients was consistent with the reported contribution of traumatic injuries, although the sex distribution varied according to the underlying cause of the defect.

The mean age of 49.3 years reflects the inclusion of patients with chronic neuropathic lesions and malignancy, in addition to younger patients with traumatic defects. This age distribution underscores the heterogeneous nature of heel reconstruction and the need to individualize treatment according to the cause, anatomical extent, vascular status, and functional requirements of each patient.

Advantages of the medial plantar flap

The principal advantage of the medial plantar flap is its ability to provide plantar tissue for reconstruction of a weight-bearing surface. The specialized architecture of plantar skin and its underlying fibrous septa contribute to resistance against compression and shear. Although a flap cannot be assumed to reproduce every biomechanical property of the native heel pad, tissue harvested from the instep offers a more anatomically appropriate replacement than skin from many non-plantar donor sites

The medial plantar flap also provides the possibility of sensate reconstruction. Preservation and appropriate transfer of the cutaneous nerve supply may support protective sensation and improve the patient's ability to recognize potentially damaging pressure or trauma. Wan et al. evaluated the quality of innervation in sensate medial plantar flaps and highlighted the importance of sensory assessment following heel reconstruction.

The mean operative duration in the present series was approximately 110 minutes, while the mean hospital stay was 11 days. The procedure avoids microvascular anastomosis and may therefore be advantageous in appropriately selected patients when the local vascular anatomy and donor site are intact. However, these outcomes should be interpreted in the context of the study setting and patient characteristics.

Complications and flap viability

The reported complication profile included hematoma, venous congestion, partial flap necrosis, and donor-site graft loss. Hematoma was the most frequently reported complication. This finding reinforces the importance of adequate haemostasis, appropriate drain uses where indicated, and close postoperative monitoring. Venous congestion may arise from pedicle compression, torsion, excessive tension, or inadequate venous outflow. Meticulous flap inset and limb positioning are therefore essential. Partial necrosis and donor-site graft loss, although less frequently reported, may delay rehabilitation and increase the need for wound care or secondary procedures.

The reported overall complication rate was 27.6%. This figure should be verified against the original patient-level data because the individual complication percentages do not clearly reconcile with the stated total. The final analysis should distinguish the proportion of patients experiencing at least one complication from the total number of complication events.

Sensory recovery

Sensory restoration is an important objective in heel reconstruction, particularly in patients with pre-existing neuropathy. In this study, protective sensation and static two-point discrimination were reported to improve in most patients during follow-up.

Wan et al investigated the quality of innervation in sensate medial plantar flaps, providing a relevant basis for evaluating postoperative sensory function . Other studies have described variable degrees of preserved, diminished, or altered sensation after medial plantar flap transfer.[10] Sensory recovery may depend on nerve integrity, the extent of dissection, the underlying neurological condition, and the duration of follow-up.

The findings of the present study are encouraging; however, the absence of complete numerical sensory measurements limits the ability to quantify the magnitude of recovery.

Future studies would benefit from standardized baseline and postoperative sensory testing, with serial measurements and documentation of the number of patients assessed at each follow-up interval.

Recurrent ulceration and long-term durability

Prevention of recurrent ulceration is a central objective of heel reconstruction. The medial plantar flap offers tissue adapted to plantar loading, but successful reconstruction does not eliminate the risk of subsequent ulceration, especially in patients with persistent neuropathy, abnormal foot mechanics, or inadequate offloading.

In the present series, recurrent ulceration at the flap interface was reported in 3.3% of patients at approximately one year. No ulceration directly over the flap was reported in the supplied results. These findings suggest satisfactory short-term outcomes, although the limited follow-up information and absence of detailed patient-level data restrict conclusions about long-term durability.

Previous reports have described recurrent ulceration rates that vary according to patient characteristics, flap design, sensory status, and duration of follow-up.[11,12] Rashid et al compared medial plantar and reverse sural flaps for reconstruction of weight-bearing heel defects and reported differences in complications and return to work.[11] Such comparisons must be interpreted cautiously because the flaps may be selected for different defect sizes, anatomical locations, and vascular circumstances.

Patients with neuropathy require continued surveillance even when flap healing is satisfactory. Education regarding daily foot inspection, appropriate footwear, pressure redistribution, and early recognition of skin breakdown remains essential. The higher incidence of new-site ulceration reported among neuropathic patients in the supplied dataset further emphasizes the importance of managing the underlying disorder rather than focusing exclusively on the reconstructed heel.

Functional outcomes and return to activity

Walking stability improved during follow-up in the present series. The proportion of patients reporting good stability increased from 90% at six months to 93.3% at one year. The mean time to return to routine activities was approximately 45 days. These findings suggest that the medial plantar flap can support functional rehabilitation in selected patients.

Nevertheless, self-reported walking stability is a subjective outcome and may be influenced by pre-existing neuropathy, neurological impairment, contralateral limb function, footwear, and the extent of the original defect.

Future prospective studies should include validated functional measures, objective gait assessment where feasible, and standardized documentation of weight-bearing status and return to work. Such measures would allow more robust comparisons between reconstructive techniques.

Donor-site morbidity

The donor-site defect was covered with a split-thickness skin graft. Although the medial plantar flap uses tissue from a relatively protected region of the sole, donor-site healing and comfort remain important considerations. Pain, tenderness, graft loss, altered sensation and difficulty with footwear should be assessed systematically. In the present series, additional protective footwear requirements reportedly declined during follow-up. This may reflect progressive adaptation and rehabilitation, although the small sample and limited details prevent firm conclusions regarding the relationship between flap reconstruction and footwear dependence.

Clinical implications

The medial plantar flap is a reasonable reconstructive option for selected heel defects when the instep donor site is intact, the posterior tibial–medial plantar arterial circulation is adequate, and the defect can be covered without excessive tension. It may be particularly useful when sensate coverage of a weight-bearing surface is desired and a local pedicled flap can provide sufficient tissue.[13]

The technique is not suitable for every defect. Extensive tissue loss, injury to the vascular pedicle, significant peripheral arterial disease, or an unsuitable instep may require alternative reconstruction, including other regional flaps or free-tissue transfer.[14] The medial plantar flap should therefore be considered within an individualized reconstructive plan rather than as a universal solution for all heel defects.[15,16]

Limitations

This study has several limitations. First, the sample size was relatively small and derived from a single institution, limiting the generalizability of the findings. Second, complete patient-level sensory measurements and detailed numerical results for every outcome were not available. Third, the follow-up duration and number of patients assessed at each time point require clarification, particularly for outcomes described as long-term.[17-20]

The absence of a clearly documented comparison group prevents direct conclusions regarding the superiority of the medial plantar flap over alternative reconstructive techniques. Furthermore, inconsistencies in the reported complication rate and certain outcome denominators require reconciliation before statistical interpretation. Future studies with larger cohorts, standardized outcome measures, clearly defined follow-up intervals, and appropriate comparison groups are warranted.

The sensate medial plantar flap is a useful option for reconstruction of selected weight-bearing heel defects. By providing tissue from the non-weight-bearing instep, it offers a reconstructive approach that is anatomically appropriate for the plantar surface and may support protective sensation and functional rehabilitation.[21,22]

CONCLUSION

In this series, the flap was associated with a mean operative duration of 110 minutes, a mean hospital stay of 11 days, reported sensory improvement, a low reported frequency of recurrent ulceration at the flap interface, and improvement in walking stability during follow-up. These findings support its use in appropriately selected patients, although the absence of a comparison group limits conclusions about its relative effectiveness.

Successful outcomes depend on careful preoperative vascular assessment, suitable defect and donor-site selection, meticulous pedicle dissection, and structured postoperative rehabilitation. Long-term surveillance, pressure redistribution, protective footwear, and management of underlying neuropathy remain essential to reduce recurrent ulceration. Further studies with standardized outcome assessment and comparative designs are needed to establish the durability and relative effectiveness of this technique.

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