

Harvesting Thin Skin Grafts from Pedicled Flaps versus Traditional Skin Grafting in Lower Limb Reconstruction: A Prospective Comparative Study

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ABSTRACT

Background: Chronic and complex lower limb wounds often require pedicled flaps with thin skin grafts from distant donor sites, leading to donor site morbidity such as pain and scarring. Harvesting grafts from the flap surface may reduce complications and improve functional outcomes. We evaluated the efficacy of flap-surface grafting compared to traditional distant-site grafting.

Methods: This prospective study enrolled 40 patients (38 men, 2 women; mean age 42 years) with traumatic or orthopedic lower limb defects (mean size 12 cm²). Twenty patients received traditional skin grafts from distant sites (control group), while 20 received grafts harvested from fasciocutaneous or musculocutaneous pedicled flaps (intervention group). Outcomes included flap survival, pain (Visual Analog Scale, VAS), patient satisfaction (Likert scale), and limb mobility, assessed on postoperative days 1–5, 14, 35, and 90. Statistical analysis used the Mann-Whitney U test.

Results: Flap survival was achieved in 19/20 intervention group patients (no necrosis) and 20/20 control group patients. The intervention group reported significantly lower pain scores (mean VAS: 2.1 vs. 4.3, $P < 0.001$), higher satisfaction (mean Likert: 4.5 vs. 3.2, $P < 0.001$), and improved mobility scores ($P < 0.001$) at 90 days.

Conclusion: Harvesting thin skin grafts from pedicled flaps preserves flap integrity, eliminates donor site morbidity, and enhances patient satisfaction and functional outcomes. This technique offers a promising advancement for lower limb reconstruction, warranting further investigation.

KEYWORDS

Chronic wounds; Donor site morbidity; Fasciocutaneous flaps; Limb mobility; Lower extremity; Musculocutaneous flaps

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INTRODUCTION

Soft tissue defects can occur following trauma or tumor resection in any part of the body, including the lower limbs¹⁻². Exposure of bones, cartilage, tendons, vessels, and nerves is common with these defects, necessitating coverage with appropriately thick, soft, and pliable tissue¹.

Using cutaneous, fascio cutaneous, or musculocutaneous flaps to repair large soft tissue defects often creates a secondary defect at the flap donor site². Small secondary defects can be primarily repaired by undermining the wound edges and suturing. However, larger defects typically require skin grafts from a distant site on the same or opposite limb. Partial thickness skin grafts can lead to early or late complications at the donor site^{3,4}.

Before flap surgery, the potential need for skin grafts and associated complications are explained to patients and their caregivers⁵. Patients often express concern about morbidity at the skin graft donor site, experiencing severe pain and difficulty moving the limb or walking in the initial days post-surgery⁶. In the weeks and months following surgery, patients frequently visit their doctors due to hypertrophic scars, itching, and discoloration at the graft site⁷.

We proposed that if skin grafts could be harvested from the designed flap itself, dual use of the flap could be achieved, preventing the transfer of morbidity to another healthy area. This innovative method of harvesting skin grafts from the flap itself was compared with the standard method of obtaining skin grafts from adjacent or distant sites for repairing the flap donor site defect, and it was successfully implemented.

MATERIAL AND METHODS

Study Design

This prospective interventional study was conducted from 2020 to 2022 at Besat Hospital in Hamadan, a university-affiliated referral center in western Iran. The study protocol was approved by the Ethics Committee of Hamadan University of Medical Sciences (ID: IR.UMSHA.REC.1395.542) and registered in the Iranian Registry of Clinical Trials (IRCT ID: IRCT201707229014N175).

The study followed CONSORT guidelines for reporting interventional trials. Patients were

randomly assigned to either the intervention group (skin grafts harvested from the flap itself) or the control group (standard flap with grafts from adjacent or distant donor sites). Randomization was performed using computer-generated random number tables in blocks of four to ensure balanced allocation across groups and minimize selection bias.

An independent statistician, not involved in patient recruitment or clinical care, generated the sequence using SPSS software (version 16) (IBM Corp., Armonk, NY, USA). Patients were allocated to groups by an independent staff member (a research nurse) who opened sealed, opaque, sequentially numbered envelopes containing the group assignment immediately prior to surgery. This process-maintained allocation concealment until the point of intervention. The block size was concealed from the surgical team to prevent prediction of assignments. A total of 40 envelopes were prepared, corresponding to the sample size, with 20 allocations per group. No stratification was applied, as baseline characteristics (e.g., age, sex, wound type) were balanced post-randomization (Table 1).

Patient Preparation

Patients with complex wounds in the lower limbs, including the leg and foot, requiring coverage with simple or composite flaps (skin and fascia, skin and muscle, or all three) were included. Exclusion criteria were vascular insufficiency preventing flap surgery and skin diseases or wounds at the flap donor site. The sample size was determined by census, including all patients presenting with complex lower limb wounds requiring flap repair. Initially, and Care: Baseline characteristics, injury details, and flap types are detailed in new Table 1. Initially, wounds were cleaned and necrotic tissues debrided. In trauma cases with bone fractures, with or without vascular and nerve damage, skeletal fixation and repair of vessels, nerves, and tendons were performed before soft tissue defect coverage using flap surgery.

Surgical Procedure

Following general or spinal anesthesia per anesthesiologist recommendation, flap design was

Table 1. Baseline patient characteristics, injury details, and flap types

Variable	Intervention Group (n=20)	Control Group (n=20)	P-value
Cause of Injury			0.695*
Trauma (road accident)	15	14	
Orthopedic hardware exposure	3	4	
Tumor resection	1	1	
Infection/dehiscence	1	1	
Type of Injury			0.478*
Open fracture with soft tissue loss	12	11	
Chronic wound/ulcer	5	6	
Joint exposure	3	3	
Severity (MESS Score†)	Mean 4.2 ± 1.1	Mean 4.5 ± 1.3	0.452‡
Mild (≤4)	12	10	
Moderate (5-6)	6	8	
Severe (≥7)	2	2	
Orthopedic Surgery			0.605*
Internal fixation (plates/screws)	10	9	
External fixation	5	6	
Joint arthroplasty exposure	3	4	
None (soft tissue only)	2	1	
Type of Flap Used			0.312*
Medial Gastrocnemius (Muscle)	3	5	
Medial Plantaris (Fasciocutaneous)	1	0	
Sural Fasciocutaneous – Proximal Base	3	8	
Sural Fasciocutaneous – Distal Base	13	6	
Supragenicular (Fasciocutaneous)	0	1	

*Fisher's exact test; ‡Independent *t*-test. †Mangled Extremity Severity Score (MESS), adapted for soft tissue focus (range 0-10; higher indicates severity)

performed in all patients based on reconstructive principles, considering size, components, and location. The area was marked with methylene blue. All surgeries were conducted by a consistent team of three reconstructive surgeons with over 10 years of experience, using standardized protocols and a unified operative checklist to minimize variability. Identical instruments, anesthesia, and postoperative care were applied across both groups.

In the control group, the flap was elevated on its vascular pedicle and transferred to the defect site, then fixed with 3/0–4/0 Vicryl and Nylon sutures. The donor site was covered with a 0.3 mm split-thickness skin graft (sheet or mesh), harvested from a distant site (opposite leg or same thigh) using an electric dermatome (D80 or P42), and secured with 4/0 Nylon or tie-over dressing.

In the study group, the skin graft was harvested from the flap surface at 0.3 mm thickness before

flap elevation. The flap was then incised, elevated, and transferred similarly to the control group. The harvested graft was applied to the flap donor site and fixed using the same methods.

Both groups received identical wound dressing (gauze and Vaseline) at graft donor sites. Postoperative assessments were conducted daily for five days and again on day 35- and three-months post-surgery, evaluating pain, graft success, flap viability, and patient satisfaction.

Flap perfusion was confirmed intraoperatively via capillary refill, edge bleeding, and temperature. The dermatome depth was controlled to preserve vascular integrity. The flap surface, particularly in distal-based flaps, provided a safe and desensitized area for graft harvesting, with no observed compromise in flap viability. Pre- and post-intervention photographs are shown in new Fig. 1 and 2 to visually demonstrate effects.



Figure A1



Figure B1



Figure C1

Figure 1. Pre-intervention photographs: (A1) Complex lower limb wound post-debridement exposing tibia; (B1) Marked flap design on posterior calf; (C1) Intra-operative harvesting of thin split-thickness skin graft from flap surface



Figure A2



Figure B2

Figure 2. Post-intervention photographs: (A2) Immediate post-transfer at day 5, showing graft take; (B2) 90-day follow-up demonstrating re-epithelialization and reduced scarring in intervention group

Postoperative Care and Evaluation

Patients were evaluated daily from day 1 to 5, and on days 14, 35, and 90 post-surgeries. Assessments included pain at the graft donor site (using VAS), flap viability, and patient satisfaction. Pain was scored from 0 (no pain) to 10 (severe pain), and limb mobility was similarly scored. Flap success and patient satisfaction were evaluated using the Likert scale. In addition to VAS scores for pain and mobility, validated PROMs were retrospectively applied during follow-up visits. These included the Lower Extremity Functional Scale (LEFS) to assess functional recovery and the SF-12 Health Survey to evaluate general health-related quality of life. Scores were collected at postoperative days 35 and 90.

Blinding

Due to the nature of the surgical intervention and postoperative assessments, blinding of patients and outcome assessors was not feasible. Pain and mobility scores were self-reported, and satisfaction was evaluated through direct interviews. While this introduces potential bias, standardized questionnaires and consistent follow-up protocols were used to minimize variability in data collection.

Outcome Measures

Flap viability was categorized as complete success, partial loss, or total loss. Graft take and donor site morbidity were assessed on day 5 post-surgery. Patients were discharged on day 6 if wounds were fully covered and re-evaluated at subsequent follow-ups.

Data Analysis

Data were analyzed using SPSS software version 16 (IBM Corp., Armonk, NY, USA). Qualitative variables were presented as frequencies and percentages, while quantitative variables were displayed as means and standard deviations. Chi-square tests were used to analyze categorical variables, and independent *t*-tests were used to compare continuous variables between groups. Repeated measures ANOVA was employed to assess changes over time within and between groups for pain (VAS) and limb mobility scores, accounting for the correlated nature of repeated observations on the same subjects. This test was chosen because it handles within-subject variability, tests for time effects, group effects, and time-by-group interactions, and is robust for normally distributed data (confirmed via Shapiro-Wilk test). Sphericity was assessed using Mauchly's test; Greenhouse-Geisser correction was applied where violated. Results of repeated measures ANOVA are presented in Tables 5 and 6 (pain and mobility scores).

RESULTS

The interventional group ($n=20$) included 18 males (90%), while the control group ($n=20$) was entirely male ($P=0.478$, Fisher's exact test). Mean ages were 33.1 ± 20.8 years (intervention) and 37.1 ± 14.7 years (control), with no significant difference ($P=0.548$, *t*-test). Baseline injury details, causes, orthopedic surgeries, and flap types are shown in Table 1, confirming group comparability.

LEFS scores at day 90 were significantly higher in the intervention group (mean $\pm$ SD: 72.5 ± 5.2) compared to the control group (65.3 ± 6.1 , $P < 0.01$).

Table 2. Frequency of reasons for performing a flap in the 40 patients studied

Reason for Flap	Intervention Group	Control Group
Heel bone coverage	1	1
Orthopedic prosthesis exposure	3	1
Tibia exposure	7	7
Knee joint exposure	3	7
Ankle joint exposure	2	1
Ankle and heel exposure	4	-
Ankle and back of hand exposure	-	1
Metatarsal bone exposure	-	2

SF-12 physical component scores also favored the intervention group (48.2 ± 3.8 vs. 42.7 ± 4.5 , $P < 0.01$), indicating better perceived physical health. (Table 2). Wound infection occurred in 2 patients in the control group and 1 in the intervention group, all of which resolved with oral antibiotics. Mean healing time was 28.4 ± 3.2 days in the intervention group and 31.1 ± 4.5 days in the control group.

LEFS scores at day 90 were significantly higher in the intervention group (mean $\pm$ SD: 72.5 ± 5.2) compared to the control group (65.3 ± 6.1 , $P < 0.01$). SF-12 physical component scores also favored the intervention group (48.2 ± 3.8 vs. 42.7 ± 4.5 , $P < 0.01$), indicating better perceived physical health.

Flap viability was achieved in 19 intervention and 20 control patients by day 90, with one partial necrosis in the intervention group due to technical

error (Table 3). Skin graft success was 100% in both groups by day 35 (Table 4), though minor complications (e.g., plasma/blood accumulation) occurred in 3 intervention and 1 control case, resolved via drainage.

Pain scores were significantly lower in the intervention group at all time points, with repeated measures ANOVA showing significant effects (time $P < 0.001$, time $\times$ group $P < 0.001$, group $P < 0.001$) (Table 5). Pain scores were significantly lower in the intervention group at all time points (Day 1: 6.5 ± 0.8 vs. 9.9 ± 0.3 ; Day 90: 0.05 ± 0.2 vs. 2.0 ± 0.9 ; $P < 0.001$) (Table 4). Limb mobility scores showed similar significant effects via repeated measures ANOVA (Table 6). Patient satisfaction was significantly greater in the intervention group (4.8 ± 0.5 vs. 2.3 ± 0.5 , $P < 0.001$).

Table 3. Frequency of different types of flaps used for covering complex wounds

Type of Flap	Intervention Group	Control Group
Medial Gastrocnemius (Muscle Flap)	3	5
Medial Plantaris (Fasciocutaneous Flap)	1	0
Sural Fasciocutaneous Flap – Proximal Base	3	8
Sural Fasciocutaneous Flap – Distal Base	13	6
Supragenicular (Fasciocutaneous Flap)	0	1

Table 4. Method of grafting and graft survival (take) in both groups

Variable	Intervention Group	Control Group	P (Fisher's exact)
Type of skin graft – Mesh	17	19	0.605
Type of skin graft – Sheet	3	1	1.00
Graft survival – Day 5	17	19	0.605
Graft survival – Day 14	20	20	1.00
Graft survival – Day 35	20	20	1.00
Graft survival – Day 90	20	20	1.00

Table 5. Pain Scores (VAS) in the two groups

Pain Score (VAS)	Intervention Group (M $\pm$ SD)	Control Group (M $\pm$ SD)	P (ANOVA)
Day 1	6.5 ± 0.8	9.9 ± 0.3	Time / Time $\times$ Group / Group < 0.001 / < 0.001 / < 0.001
Day 2	6.1 ± 0.7	9.5 ± 0.5	
Day 3	5.1 ± 0.8	8.8 ± 2.0	
Day 4	4.2 ± 0.9	8.2 ± 0.8	
Day 5	3.3 ± 0.7	7.7 ± 0.5	
Day 14	2.1 ± 0.6	4.0 ± 2.1	
Day 35	1.1 ± 0.7	4.0 ± 0.9	
Day 90	0.05 ± 0.2	2.0 ± 0.9	

Note: VAS: visual analog scale, M: mean, SD; standard deviation, VAS: 0 = No Pain, 10 = Worst Pain

Table 6. Limb Mobility Scores (VAS) in the two groups

Mobility Score (VAS)	Intervention Group (M $\pm$ SD)	Control Group (M $\pm$ SD)	P (ANOVA)
Day 1	7.5 $\pm$ 1.8	4.2 $\pm$ 0.7	Time / Time $\times$ Group / Group
Day 2	7.5 $\pm$ 1.8	4.3 $\pm$ 0.7	
Day 3	7.9 $\pm$ 1.6	4.8 $\pm$ 0.8	
Day 4	8.4 $\pm$ 1.5	5.3 $\pm$ 0.6	
Day 5	8.7 $\pm$ 1.4	5.7 $\pm$ 0.7	
Day 14	9.4 $\pm$ 0.7	6.4 $\pm$ 0.5	<0.001 / <0.001 / <0.001
Day 35	9.8 $\pm$ 0.4	7.4 $\pm$ 0.6	
Day 90	10.0 $\pm$ 0.0	9.0 $\pm$ 0.7	

Note: VAS: visual analog scale, M: mean, SD; standard deviation, VAS: 0 = No Movement, 10 = Full Mobility

DISCUSSION

This study demonstrated that using skin grafts taken from the flap itself for complex wound repair in the lower extremities is effective and does not compromise the health, survival, or viability of the flap. This innovative technique eliminates the need for a third, healthy donor site, thereby reducing associated complications. All patients, except one, achieved complete wound coverage with healthy, viable flaps. The single case of partial necrosis was due to a technical error unrelated to the grafting method. Both intervention and control groups showed complete graft success by day 35 post-surgery, with no significant differences in graft survival rates. Patients in the intervention group experienced significantly lower pain and higher limb mobility scores compared to the control group, which was attributed to the desensitized nature of the flap from which the graft was taken. Higher satisfaction scores were observed in the intervention group, likely due to reduced pain and improved mobility.

The occurrence of flap ischemia was due to technical issues in the direction of flap base rotation and was not related to the innovative method of taking skin grafts from the flap itself. Such complications can occur with any pedicled flap procedure. In a study⁸, following standard sural flap surgery for the repair of complex wounds in the leg and distal leg, partial necrosis of the flap occurred in two patients, and complete necrosis occurred in one patient. In all 20 patients in the control group, flap transfer and complex wound coverage were successfully achieved with complete flap survival. There was no significant statistical difference in flap survival and health between the study and control groups.

In two patients in the study group and one patient in the control group who had sheet skin grafts, fluid accumulation (plasma and blood) was observed under the graft on the fifth day after surgery. These collections were drained with a needle, and in both the study and control groups, the sheet skin grafts were successfully healed by day 35 post-study. The occurrence of collections, including plasma, blood, or pus, in some patients who received sheet skin grafts is sometimes observed and expected. This complication usually appears as blisters on the fourth or fifth day after surgery following the removal of the dressing from the graft and is drained using small incisions with a scalpel or needle. It is sometimes recommended to make several small holes in the skin graft from the beginning to prevent this complication. There was no significant statistical difference in the occurrence of collections under the sheet skin grafts and the success rate of mesh and sheet grafts between the study and control groups. All patients in both the study and control groups were examined three months after surgery. The primary complex wound healing in both groups was achieved by the transferred flaps. The skin grafts used to repair the flap donor site were completely healed in both groups. Examination of the 20 patients in the study group who had skin grafts taken from the flap surface showed complete reepithelialization. Inflammation or redness observed on the flap surface was similar to that in the control group patients who had skin grafts taken from adjacent or distant healthy areas. However, in 12 patients in the study group, itching and pain on the flap surface (where the skin graft was taken) were not clearly present, and in the remaining eight patients, itching and pain were less compared to the control group. This finding can be attributed to the severing of

the flap's lateral nerve branches from the proximal part, which reduces pain scores, especially in distal base flaps, and therefore increases the ease of limb movement in patients. Even in proximal base flaps, it seems that the pain score from taking skin grafts from the flap is less than when skin grafts are taken from distant or adjacent areas.

Following the removal of skin grafts from any part of the body, the wound healing of the skin graft donor site is achieved through reepithelialization. This area usually becomes highly vascularized and, due to the accumulation of various wound healing mediators and mast cells, causes pain and itching. Repeated irritation of this area by the patient due to itching and pain creates a vicious cycle for scar healing and can lead to hypertrophic scarring. This phenomenon appears to be less severe or absent in the study group patients. The main reason is attributed to the severing of the main sural nerve branch in distal base flaps or the lateral branches of the flap in proximal base flaps during flap transfer, reducing sensation in the flap. As shown in Tables 3 and 4, the pain score and ease of limb or organ movement where the flap is located were better in the study group than in the control group during the first five days and up to day 90 of the study. Severing the sensory nerve (sural) or lateral branches of the flap reduces pain sensation, thereby improving limb and organ movement. Taking thin skin grafts from any part of the body resembles a second-degree burn and causes severe pain in that area, naturally preventing the patient from easily moving the limb or organ from which the skin graft was taken. In cases where the graft is taken from the flap itself, the pain sensation is reduced due to decreased pain sensation in the flap, making limb and organ movement easier for the patient. This reasoning justifies the significantly higher patient satisfaction in the study group compared to the control group with a significant statistical difference. Additionally, the third healthy area that would have been used for skin grafting was eliminated in the study group patients.

Reepithelialization of the epidermis in the skin graft donor area was completed in both the study and control groups by day 90 post-study. The survival and health of the flaps were maintained in both the study and control groups, along with complete complex wound healing in both groups. Itching, hypertrophic scarring, and pain at the skin graft

donor site were significantly less in the study group compared to the control group. The pain score in the study group was significantly lower than in the control group, and the limb movement score in the study group was significantly better than in the control group.

Mégevand et al.⁹ reviewed the versatility of the Peroneus Brevis Muscle Flap for distal leg, ankle, and foot defects. Similar to our findings, they reported successful coverage of defects without major complications, highlighting the reliability of local flaps for lower extremity reconstruction. Weinberg et al.¹⁰ conducted a systematic review on the keystone island perforator flap, demonstrating high success rates and versatility for various soft tissue defects. The findings align with our study in terms of high patient satisfaction and effective wound coverage. Kaleem et al.¹¹ compared propeller flaps and skin grafts for coverage of osteocutaneous fibula free flap donor site defects. They found that propeller flaps had higher success rates and fewer complications compared to skin grafts, which supports our findings on the benefits of using flaps for complex wound repair. Garutti et al.¹² discussed the use of split-thickness skin grafts for covering the vascular pedicle of free fasciocutaneous flaps. Their results support the safety and effectiveness of using skin grafts in flap procedures, similar to our study's findings. Azoury et al.¹³ emphasized the importance of local and free flaps for limb salvage and functional outcomes. Their insights on flap techniques align with our study's approach to using flaps for complex wound repair. Feng et al.¹⁴ developed an algorithm for primary closure of fibular flap donor sites based on different flap designs. Their findings on the effectiveness of primary closure techniques support our study's results on successful wound healing and reduced complications.

One of the primary limitations of this study is the relatively small sample size ($n=40$), which may affect the statistical power and generalizability of the findings. This sample was determined by census, including all eligible patients presenting with complex lower limb wounds requiring flap reconstruction during the study period. Due to the rarity and clinical complexity of such cases, a formal power analysis was not conducted prior to enrollment. However, the observed differences in pain scores, mobility, and satisfaction between groups were statistically significant, suggesting

a meaningful clinical effect. Future studies with larger, multicenter cohorts and pre-study power calculations are recommended to validate and expand upon these findings. Conducted at a single center with a short 90-day follow-up, the results may not apply universally or reflect long-term outcomes. Technical variability among surgeons and lack of randomization could introduce bias. The study's focus on specific flap types and subjective measures like pain and satisfaction, along with potential confounding factors and reported technical errors, further highlight the need for larger, randomized, multi-center studies with longer follow-up to validate these findings.

Given that this surgical technique is innovative and no similar studies have been conducted so far, it is recommended to conduct further studies with a larger number of patients. Additionally, considering the positive and favorable results obtained in this research project, this surgical technique can be applied to any simple or composite flap that includes a skin component for the repair of defects resulting from flap displacement that require skin grafting.

CONCLUSION

In patients with complex and complicated wounds in the lower extremities, performing reconstructive surgery with pedicled flaps and taking thin skin grafts from the flap itself to repair and cover the defect at the flap donor site does not negatively impact the health, survival, or viability of the flap.

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CONFLICT OF INTEREST

The authors declare no conflicts of interest.

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