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Free and Pedicled Flaps for Reconstruction of the Weightbearing Sole of the Foot: A Comparative Analysis of Functional Results

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ABSTRACT

Reconstruction of the weightbearing sole of the foot is complex and requires soft tissue that is resistant to weight, pressure, and shear stress. Despite a variety of flap types and techniques, it is still challenging to meet these demands. The present retrospective study included 21 patients after reconstruction of plantar tissue defects from 2001 to 2011. The outcome was evaluated using the lower extremity functional scale, Weber score, pedobarography, assessment of shifting, and sensory recovery. The patients' quality of life was documented using the SF-36 questionnaire. Plantar reconstruction was performed using 12 free and 9 pedicled flaps. No differences in functional results were observed between the flap types, despite a better sense of temperature in the adipocutaneous flaps. The extent of flap shifting was independent of the flap type and did not correlate with the functional results. Pedobarography showed a tendency for increased peak pressure and prolonged contact time in the reconstructed weightbearing plantar areas compared with the sound feet and a control group. The present study found no relevant differences in the functional results between different flap types and free or pedicled techniques. Flap selection should be based on the individual requirements and availability of donor sites.

Most extended plantar soft tissue defects are caused by mechanical, chemical, or thermal trauma. Secondarily, they can appear as a consequence of oncologic resection, peripheral artery occlusive disease, chronic venous insufficiency, diabetes/peripheral neuropathy, and decubitus. The loss of the shock-absorbing and friction-resistant plantar tissue will result in changed walking patterns and pain. Subsequent infections can potentially lead to secondary amputation (1).

The use of muscle flaps with split-thickness skin grafts versus fasciocutaneous flaps for plantar reconstruction has been controversial, and it remains unclear whether the use of innervated flaps provides improved outcomes compared with noninnervated flaps (2–6). Regardless of the chosen flap, it has been almost impossible to replace the functional complexity of the foot's weightbearing tissue (7).

The aim of the present study was to evaluate the functional results after reconstruction of the weightbearing sole of the foot using the lower extremity functional scale, Weber score, and pedobarography. In addition, sensation recovery and patient satisfaction, documented with the SF-36 questionnaire, were analyzed.

Our goal was to determine whether there was a superior flap type or transfer technique to help guide surgical decision making.

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Patients and Methods

The present retrospective study included 37 patients treated for defects in the weightbearing plantar area with either free or pedicled flaps from 2001 to 2010 in our clinic. These flaps were performed in 37 patients during the study period. After analyzing the medical history, we excluded 9 of the 37 patients because of death (n = 1), major amputation (n = 2), multidrug resistant bacteria infection (n = 2), and immobility (n = 4). In addition, 4 patients were lost to follow-up, and 3 refused to join the study because of personal matters. The inclusion criteria were mobility with a bipedal gait and at least 6 months of follow-up. Twenty-one patients met inclusion criteria and consented to participate in the study. All the patients provided written

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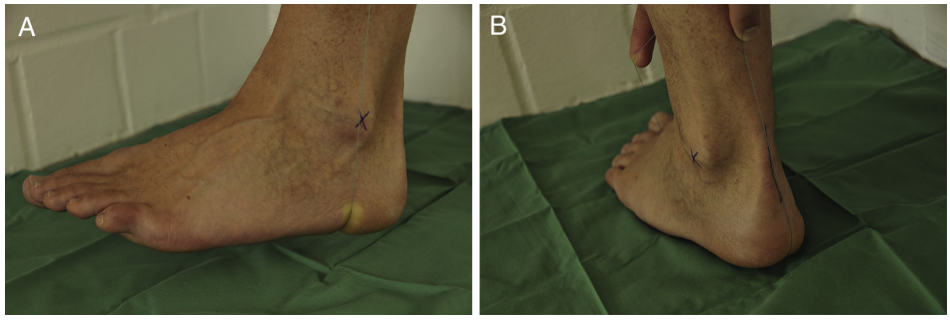

Fig. 1. (*A*) Measurement of shifting in the sagittal direction. (*B*) Measurement of shifting in the transverse direction.

informed consent before inclusion in the study. The study was performed in accordance with the Declaration of Helsinki–Ethical Treatment of Human Subjects, and the regional ethics committee approved the study protocol (Mainz, Germany, approval no. 837.176.12 8277-F).

Of the 21 included patients, 6 were female and 15 were male, with a mean follow-up period of 32.4 months. The patients were divided into different groups according to flap type and transfer technique (microsurgical versus pedicled): free flaps (n = 12) and pedicled flaps (n = 9), including fasciocutaneous flaps (n = 13), adipocutaneous flaps (n = 4), muscle flaps with split-thickness skin grafts (n = 2), and myofasciocutaneous flaps (n = 2).

Postoperative functionality was analyzed using the lower extremity functional scale (LEFS) and Weber score. The LEFS, established by Binkley et al (8), includes 20 questions concerning daily activities, reflecting patients' individual satisfaction with their functional outcome in accordance with personal expectations and requirements (maximal score 80 points). A low score reflects greater physical disability.

The Weber score evaluates the function of the talotibial joint in 6 dimensions, including radiologic changes, pain, activity, walking ability, and active range of motion. A low score indicates better functionality (9). Although the talotibial joint was not fractured in 6 patients, it was still compromised and often showed a limited active range of motion. To provide comparability (e.g., for the measured active range of motion), we decided to use the well-established Weber score.

Patient satisfaction was documented using the SF-36 questionnaire (10–12) and an esthetic questionnaire, established at our institution (data not shown).

The Vancouver scar scale (13) was used for scar assessment. Pain sensation with and without exercise was recorded using the visual analog scale (14). Sharp–blunt discrimination was determined using the sharp and blunt side of a broken wooden tongue depressor, and static 2-point discrimination with a blunt-tipped 2-point discriminator, compared with the corresponding area of the contralateral foot. The results of postoperative sensory reinnervation were classified into 3 groups (good, 80%; intermediate, 20% to 80%; and poor, <20% sensory recovery) compared with the contralateral plantar area (6). Postoperative sensory reinnervation was tested using static 2-point discrimination. Accordingly, sensory recovery was classified as good, if the static 2-point discrimination attained 80% of the values measured in the corresponding contralateral plantar area.

Thermal sensation was tested with warm (38°C) and cold (0°C) probes. All procedures were repeated 3 times. The result was considered positive in the case of 2 positive responses.

Pedobarography is a method used to measure the plantar pressure distribution. It was performed in cooperation with the physiotherapy department using the pedobarographic platform, EMED ST P9 (Novel GmbH, Munich, Germany). The measurements were performed with the patient barefoot 5 times bilaterally to compare the treated and untreated feet and with the EMED control group (52 participants; 18 males, 34 females; age range 20 to 27 years; body mass index 18 to 27 kg/m^2, without known foot problems). After plantar reconstruction, the patients' sound foot will often show alterations on gait analysis from compensative mechanisms. Therefore, EMED developed this control group to enable comparisons with healthy feet.

The flap mobility in relation to the deep tissue in the sagittal and transverse directions, the so-called shifting, was measured using a newly established evaluation technique, with a 3-0 Vicryl suture that was positioned under the flap, with the malleolus lateralis and medialis as fixed points. The suture line was marked with a pen on the flap, and the flap was pushed manually in the sagittal direction, without moving the suture. The distance between the marking and the suture was then measured. The same procedure was done in the transverse direction, with the suture and the corresponding marking positioned from the second interdigital space to the central Achilles tendon. The measurements were repeated 3 times in both directions to calculate the mean values (Fig. 1).

To evaluate the amount of shifting of the normal plantar tissue, we examined 23 male and 17 female (age range 19 to 85 years) volunteers without foot injuries. The median anterior to posterior shift was 0.23 cm (minimum 0.1 cm, maximum 0.5 cm), the median lateral to medial shift was 0.27 cm (minimum 0.1 cm, maximum 0.4 cm). Therefore, we defined a shift of 0.5 cm or more as pathologic. The postoperative working situation and the need of orthopedic shoes, orthoses or walking aids was also evaluated. Every patient was examined by the first author (V.S.), who was not a part of

Table 1
Demographic and operative data (N = 21)

Patient No.	Age (yr)	Flap	IP Time (d)	Follow-up (mo)	Location	Injury Pattern
1	56	GR	28	10	HF + MF	Trauma
2	54	DBS	49	9	HF	Trauma
3	65	MPA	35	36	HF	Trauma
4	83	ALT	46	21	HF	Trauma
5	33	PSC	42	12	HF	Trauma
6	44	PSC	32	9	FFM	Trauma
7	41	LD	33	11	HF	Trauma
8	28	PSC	87	29	HF	Trauma
9	71	LA	36	35	HF	Trauma
10	66	ALT	40	25	HF	Trauma
11	61	LA	19	34	HF	Trauma
12	30	DBS	46	98	HF	Trauma
13	36	MPA	28	23	HF	Decubitus
14	23	DBS	30	37	HF	Trauma
15	23	DBS	30	41	HF	Trauma
16	58	DBS	62	83	HF	PAOD
17	41	MPA	11	10	HF	Decubitus
18	35	DBS	18	13	HF	Trauma
19	81	ALT	24	6	FFM	Trauma
20	70	GR	22	83	HF + MF	Trauma
21	27	LD	71	139	HF + MF + FFM	Trauma

Abbreviations: ALT, anterolateral thigh (flap); DBS, distally based sural (flap); FFM, fibular foot margin; GR, gracilis flap; HF, hind foot; IP, in-patient; LA, lateral arm (flap); LD, latissimus dorsi (flap); MF, mid foot; MPA, medial plantar artery (flap); PAOD, peripheral arterial occlusive disease; PSC, parascapular flap.

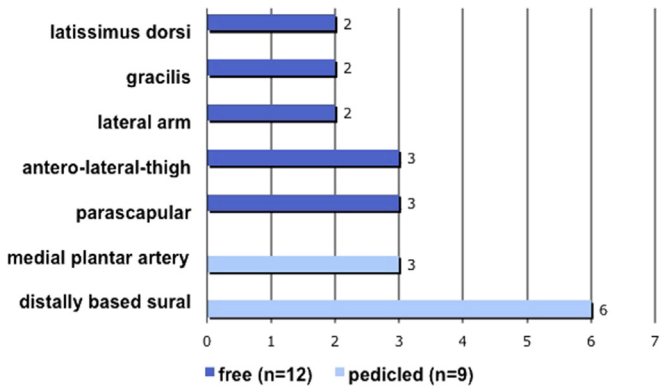

Fig. 2. Distribution of flap donor site and transfer technique.