Successful Balanced Gait after Reconstruction of the Weight-bearing Mid Plantar Region Using a Free Contralateral Medial Plantar Flap

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Summary: Although soft tissue sarcoma, especially in the sole of the foot, is a rare disease, weight-bearing region reconstruction considering postoperative gait is needed. For functionally satisfactory sole reconstruction, it is important to cover the weight-bearing region with a nonbulky but durable skin paddle that can withstand a significant amount of shear pressure. We herein present a case in which a free contralateral medial plantar flap was used for reconstruction of the weight-bearing mid plantar region for a 41-year-old man who suffered from mid-foot sarcoma. Gait analysis was performed 6 months after the operation with the lower limb loading gauge sheet, and the result indicated that postoperative balanced gait was obtained. The free medial plantar flap transfer after sole sarcoma resection has several advantages. First, the characteristic of this flap with solid anchoring to deep tissue to resist shearing makes it possible to lower the chances of postoperative ulceration. Second, the medial plantar flap has optimal thickness and good color and texture match for sole reconstruction. Third, a sensate flap can be achieved if the medial plantar nerve is included. Although further clinical investigations such as long-term follow-up will be required to confirm its efficacy, this method would be one option for treating sole sarcoma. (Plast Reconstr Surg Glob Open 2019;7:e2456; doi: 10.1097/GOX.0000000000002456; Published online 30 September 2019.)

CASE REPORT

A 41-year-old male presented to our department after resection of a tumor at the sole of his left foot, which was diagnosed as synovial sarcoma. In the prior surgery, an excision followed by primary closure was performed at another hospital and histopathological analysis revealed Federation Nationale des Centres de Lutte Contre Le Cancer system grade 2 synovial sarcoma with positive surgical margin. Therefore, additional surgical wide resection, followed by immediate reconstruction using a free contralateral medial plantar flap for treatment of mid-foot sarcoma.

Additional surgical wide resection with 1–2 cm margin, including quadratus plantae muscle, lateral plantar artery, vein and nerve, and medial plantar artery, vein, and nerve was performed. The defect after tumor ablation was 7 × 7 cm (Fig. 1). Because the medial plantar artery and vein were resected with the tumor, the local medial plantar flap could not be used. An 8 × 8 cm free medial plantar flap was...
The flap was elevated from the sole of the right foot (Fig. 2). The flap was not elevated as a sensate flap because there was no usable recipient nerve due to the wide resection. The right medial plantar artery was anastomosed to the left posterior tibial artery in an end-to-side manner. Two venae comitantes of the right medial plantar artery were anastomosed to the 2 left posterior tibial veins in an end-to-side fashion, respectively. The skin defect at the donor site was covered with full-thickness skin graft harvested from lumbar area. The histopathological analysis of the second surgery revealed no residual tumor. The radiation therapy was not performed. The postoperative course was uneventful and the free medial plantar flap survived completely (Fig. 3). Dangling was started on postoperative day 8, partial weight bearing was allowed on postoperative day 10, and full weight bearing was allowed on postoperative day 16.

Gait analysis was performed 6 months after the operation with the lower limb loading gauge sheet (Walk-way MW-1000, Tokyo, Japan). The examinee walked on a sensor sheet at his normal walking speed and the pressure distribution and the gait cycle were recorded for both feet. Static plantar pressure measurement showed the same pressure distribution in both feet (Fig. 4). The gait analysis is summarized in Table 1. The peak force at the moment of foot flat was 782.04 N in left foot and 804.58 N in right foot, respectively. Average gait cycle, stance phase, swing phase, and double stance phase were 1.08, 0.70, 0.38, and 0.17 sec in left foot, and 1.09, 0.70, 0.39, and 0.15 sec in the right foot, respectively.

**DISCUSSION**

In the setting of sarcoma surgery, radical resection and limb salvage surgery are recommended. Reconstructive technique such as pedicled or free tissue transfer is essential for limb salvage and safe resections. Although soft tissue sarcoma, especially in the sole of the foot, is a rare disease, weight-bearing region reconstruction considering postoperative gait is needed.

For functionally satisfactory sole reconstruction, it is important to cover the weight-bearing region with a nonbulky, but durable skin paddle that can withstand a significant amount of shear pressure. The pedicled ipsilateral medial plantar flap can be considered an optimal procedure of sole reconstruction not only for covering the weight-bearing area of the heel but also for the forefoot and middle plantar region. However, donor-site morbidity such as postoperative unbalanced gait is commonly seen in the case using free medial plantar flap. On the other hand, reconstruction using a free flap from non-weight-bearing area, such as the rectus abdominis flap, the latissimus dorsi flap, the scapular flap, and the anterolateral thigh flap, is likely to result in ulceration of the reconstructed area due to weak deep tissue anchoring power of those flaps. Some articles reported that thoracodorsal artery perforator flap is a favorable option in plantar reconstruction as it does provide durable coverage and fast recovery. However, because the patient did not desire the back wound, we did not choose thoracodorsal artery perforator flap.

There are few reports in which postoperative gait is evaluated after the weight-bearing reconstruction using a free contralateral medial plantar flap. In these reports, the indications for the weight-bearing reconstruction were injury or chronic wound. Moreover, they reported that it was quite difficult to obtain postoperative symmetrical gait after the reconstruction using a free contralateral medial plantar flap. In the reported case, the contralateral free medial plantar flap was used for reconstruction to prevent ulceration. As a result, well-balanced gait was obtained at postoperative 6 months. Gait analysis with the lower limb loading gauge sheet (Walk-way MW-1000) demonstrated the same pressure distribution and average gait cycle in both feet. In the case, the peak force divided by the body weight was 11.67
m/s² in left foot and 12.0 m/s² in right foot, respectively. A previous study, in which the ground reaction force variables were analyzed in hemiplegic patients (n = 20) and healthy volunteers (n = 20), reported that the peak force divided by the body weight was 11.53 ± 0.15 m/s². Therefore, we concluded that well-balanced normal gait not only in the reconstructed foot but also the donor side foot was obtained after reconstruction.

The free medial plantar flap transfer after sole sarcoma resection has several advantages. First, the characteristic of this flap with solid anchoring to deep tissue to resist shearing makes it possible to lower the chances of postoperative ulceration. Unlike in reconstruction of a diabetic foot, recurrence of sarcoma has to be considered in every ulceration after sarcoma treatment. Second, the medial plantar flap has optimal thickness and good color and texture match for sole reconstruction. Third, a sensate flap can be achieved if the medial plantar nerve is included. One of the drawbacks of this method is the delay of start of walking. However, we strongly believe that this is acceptable for expected long-term result.

CONCLUSIONS

We experienced a case in which postoperative balanced gait was obtained after the weight-bearing mid plantar region was reconstructed using a free contralateral medial plantar flap for reconstruction after mid-foot sarcoma resection. Although further clinical investigations such as long-term follow-up will be required to confirm its efficacy, this method would be 1 option for treating sole sarcoma.

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Table 1. Foot Measurement

| Parameter          | Left Foot (Affected Side) | Right Foot (Donor Side) |
|--------------------|---------------------------|-------------------------|
| Peak force (N)     | 782.04                    | 804.58                  |
| Peak force/BW (N/kg) | 11.67                    | 12                      |
| Gait cycle (s)     | 1.08                      | 1.09                    |
| Stance phase (s)   | 0.7                       | 0.7                     |
| Swing phase (s)    | 0.38                      | 0.39                    |
| Double stance phase (s) | 0.17                    | 0.15                    |
| Stride (cm)        | 100.5                     | 101.1                   |
| Step length (cm)   | 48.7                      | 52.3                    |
| Stride width (cm)  | 12.9                      | 11.4                    |
| Toe-out angle (°)  | 14                        | 12                      |

All measurements were performed with the lower limb loading gauge sheet (Walk-way MW-1000).

BW, body weight; N, Newton.
REFERENCES

1. Rausky J, Binder JP, Mazouz-Dorval S, et al. Perforator-based chi- 
maeric thoracodorsal flap for foot reconstruction. J Plast Reconstr 
Aesthet Surg. 2013;66:1798–1800.

2. Sen SK, Fitzgerald O’Connor E, Tare M. The free instep flap 
for palmar and digital resurfacing. J Plast Reconstr Aesthet Surg 
2015;68:1191–1198.

3. Pappalardo M, Jeng SF, Sadigh PL, et al. Versatility of the free 
anterolateral thigh flap in the reconstruction of large defects of 
the weight-bearing foot: a single-center experience with 20 con- 
secutive cases. J Reconstr Microsurg. 2016;32:562–570.

4. Mattei JC, Brouste V, Terrier P, et al. Distal extremities soft tissue 
sarcomas: are they so different from other limb localizations? J 
Surg Oncol. 2019;119:479–488.

5. MacArthur IR, McInnes CW, Dalke KR, et al. Patient reported 
outcomes following lower extremity soft tissue sarcoma resec- 
tion with microsurgical preservation of ambulation. J Reconstr 
Microsurg. 2019;35:168–175.

6. Scheufler O, Kalbermatten D, Pierer G. Instep free flap for 
plantar soft tissue reconstruction: indications and options. 
Microsurgery. 2007;27:174–180.

7. Drake DB. Reconstruction for limb-sparing procedures in soft-tis- 
sue sarcomas of the extremities. Clin Plast Surg. 1995;22:123–128.

8. Ozger H, Eralp L, Türker M, et al. Surgical treatment of malignant 
tumors of the foot and ankle. Int J Clin Oncol. 2005;10:127–132.

9. Bach AD, Kopp J, Stark GB, et al. The versatility of the free osteo-
cutaneous fibula flap in the reconstruction of extremities after 
sarcoma resection. World J Surg Oncol. 2004;2:22.

10. Hong JP, Kim EK. Sole reconstruction using anterolateral thigh 
perforator free flaps. Plast Reconstr Surg. 2007;119:186–193.

11. Scaglioni MF, Rittirsch D, Giovanoli P. Reconstruction of the 
heel, middle foot sole, and plantar forefoot with the medial plantar 
artery perforator flap: clinical experience with 28 cases. Plast 
Reconstr Surg. 2018;141:200–208.

12. Paget JT, Izadi D, Haj-Basheer M, et al. Foot Ankle Surg. 
2015;21:60–66.

13. Oztürk S, Bayram Y, Möhür H, et al. Evaluation of late func- 
tional results of patients treated with free muscle flaps for heel 
defects caused by land-mine explosions. Plast Reconstr Surg. 
2005;116:1926–1936.

14. Lee KT, Park SJ, Mun GH. Reconstruction outcomes of onco-
logic foot defect using well-contoured free perforator flaps. Ann 
Surg Oncol. 2017;24:2404–2412.

15. Nohira K, Shintomi Y, Sugihara T, et al. Replacing losses in kind: 
improved sensation following heel reconstruction using the free 
instep flap. J Reconstr Microsurg. 1989;5:1–6.

16. Kim HD, Kim JG, Jeon DM, et al. Analysis of vertical ground reaction 
force variables using foot scans in hemiplegic patients. Ann 
Rehabil Med. 2015;39:409–415.