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Anterolateral Thigh Flap for Soft Tissue Reconstruction of the Heel and Plantar Defects with Sensory Reinnervation

Topuk ve Plantar Bölge Defektlerinde Duyusal Serbest Anterolateral Uyluk Flebinin Kullanımı

Serkan YILDIRIM[a], Gaye TAYLAN FİLİNTE[b], Çağla ÇİÇEK[b], Tayfun AKÖZ[a]

[a]Private Clinic of Plastic, Reconstructive and Aesthetic Surgery, İstanbul, TURKEY
[b]Department of Plastic, Recontructive and Aesthetic Surgery, Kartal Dr. Lütfi Kırdar Training and Research Hospital, İstanbul, TURKEY

ABSTRACT Objective: The limited local soft tissue and the special characteristics of the heel and plantar region is a challange for the reconstructive surgeons. The reconstruction strategies should provide a skin tissue resistant to weight-bearing and shear forces, enough soft tissue to absorbe, protective sensation, and a proper contour. **Material and Methods:** Eight patients were treated for soft-tissue defects in the heel and plantar areas with free anterolateral thigh flaps. Sensory nerve coaptation was performed in all cases. The follow-up period ranged from 24 to 53 months. The patients' ages ranged from 16 to 60 years (mean 39 years). **Results:** All flaps survived. A secondary debulking procedure was performed for 1 flap at postoperative 12th month. Self-resolving minor abrasions were observed in 2 flaps at the end of the first year. Partial weight bearing was allowed at 4th and full weight bearing at the 8th weeks. The time period until full ambulation averaged 3 months. All patients were sensitive to deep pressure, whereas only 5 recognized light touch. **Conclusion:** The unique characteristics of the anterolateral thigh flap provide optimal results both in the early and late follow-ups when used for this region. The innervated anterolateral thigh flap was preferred in this study due to the advantages achieved earlier than the noninnervated flaps.

Keywords: Heel reconstruction; anterolateral thigh flap; microsurgery

ÖZET Amaç: Topuk ve plantar bölgedeki sınırlı yumuşak doku rezervi plastik cerrahlar için sıklıkla zorlayıcıdır. Bu bölgelerin rekonstrüksiyonlarında dikkat edilmesi gereken temel prensipler; ağırlık taşıyan bir bölge olması dolayısı ile yük taşıyabilecek ve sürtünme kuvvetlerine dirençli bir cilt dokusu getirilmesi, uygun anatomik şekilli ve duyusu olan yumuşak doku desteğinin sağlanmasıdır. **Gereç ve Yöntemler:** Çalışmada topuk ve plantar bölge yumuşak doku rekonstrüksiyonu için serbest anterolateral uyluk flebi kullanılan 8 olgu retrospektif olarak incelenmiştir. Tüm olgularda duyusal uyarımın sağlanması için sinir koaptasyonu uygulanmıştır. Hastaların takip süresi 24-53 ay, yaş aralığı ise 16-60 idi (ortalama 39). **Bulgular:** Çalışmaya dahil edilen tüm hastaların flepleri yaşamış olup ameliyat sonrası 12. ayda 1 flep için inceltme amacıyla debulking uygulandı. Uygulanmış 2 flepte 1 yılın sonunda spontan iyileşen abrazyonlar gözlendi. Tüm fleplere 4. haftada kısmi ağırlık taşımasına, 8 haftada ise tam ağırlık taşımasına izin verildi. Tam ambulasyona kadar geçen süre ortalama 3 ay idi. Hastaların tamamı derin basınç duyusuna duyarlı iken sadece 5 tanesi sadece dokunma duyusuna duyarlı tespit edildi. **Sonuç:** Literatürde anterolateral uyluk flebinin sinir koaptasyonu ile defekte adapte edilmesi sıklıkla gösterilmiştir. Anterolateral uyluk flebinin benzersiz özellikleri, bu bölge için kullanıldığında hem erken hem de geç takiplerde en iyi sonuçları sağlar. Çalışmamızda duyulu anterolateral uyluk flebinin tercih edilmesinin sebebi, bu bölge rekonstrüksiyonu için duyusuz getirilen fleplerin mevcut dezavantajları nedeniyledir.

Anahtar Kelimeler: Topuk rekonstrüksiyonu; anterolateral uyluk flebi; mikrocerrahi

The reconstruction of the heel is a challenge because of the limited availability of local soft tissue and the special structural and functional characteristics of this particular region.[1] The plantar reconstruction of weight-bearing areas involves the need for withstanding weight-bearing pressure and shearing force, for having protective sensation, and for appropriate footwear that fits properly.[2] The unique characteristics of this region deserve special attention with regard to the following: the different characteristics of the skin and subcutaneous tissue, the weight-bearing capacity of the foot and its relation to the

Correspondence: Çağla ÇİÇEK
Department of Plastic, Recontructive and Aesthetic Surgery, Kartal Dr. Lütfi Kırdar Training and Research Hospital, İstanbul, TURKEY/TÜRKİYE
E-mail: caglamutkan2002@yahoo.com

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environment, and the ambulatory function. Reconstruction strategies should provide skin tissue that is resistant to weight-bearing and shear forces, has sufficient soft tissue for effective absorption, offers protective sensation, and has a proper contour. The management of complex foot defects has evolved from largely conservative approaches to much more aggressive protocols.[3] While small defects can be reconstructed by local flaps and skin grafts, extensive defects encompassing the pressure zones may require free flap transfers.[4] Skin grafts do not meet the requirements of this special area, and they are vulnerable to trauma and pressure.[5] The medial plantar flap, the lateral calcaneal flap, and the dorsalis pedis flap may provide sensation; however, they have many disadvantages such as limited tissue supply, difficult flap dissection, and problems association with tissue transfer from the trauma zone.[6-8] The advances in microsurgery with high rates of flap survival have enabled the routine use of free flaps for the reconstruction of this region.

This study used anterolateral thigh flaps for reconstruction of heel and plantar defects with sensory restoration. As demonstrated in the literature, sensate reconstruction has been advocated when possible.[2] Sensory reconstruction plays a significant role in avoiding ulceration and obtaining normal gait in reconstruction of the weight-bearing area of the sole.[4] The unique characteristics of the anterolateral thigh flap have resulted in optimal results both in the early and late follow-ups. The purpose of this report is to present our experience in using the anterolateral thigh flap for reconstruction of heel and plantar defects with sensory restoration.

MATERIAL AND METHODS

This study presents eight cases (including two males and six females) of reconstruction of the heel and plantar areas. The patients' ages ranged from 16 to 64 years (mean 39 years). The causes of the tissue losses were trauma (n=4), skin cancer (n=3), and postburn contracture deformities (n=1). All patients underwent reconstruction with anterolateral thigh flaps for the heel and plantar defects (Table 1). The study was planned retrospectively in accordance with the principles of the Declaration of Helsinki, 2008. The approval of the ethics committee was not obtained because the study was retrospective. Informed consent forms were obtained from the patients, or from their legal representatives if necessary, before surgery.

The flap elevation is performed as follows. The intermuscular septum is palpated between the rectus femoris and the vastus lateralis muscles, and then the line is drawn between the anterior superior iliac spine and the lateral border of the patella over the septum. The midpoint of this line is determined and used as the center of the circle, and a circle is drawn with a 5-cm radius. The location of the perforators is detected with a hand-held Doppler probe within this circle. The flap margins are marked according to the required tissue amount. First, the medial margin of the flap is incised down to the deep fascia, and the flap is elevated to the midline in the subfascial plane to locate the perforators. The largest of the perforators is selected, and the position of the flap is managed according to this perforator. The other three margins of the flap are incised down to the deep fascia. With the exception of the se-

TABLE 1: Patient characteristics.

Case	Sex	Age	Size (cm)	Thickness (mm)	Etiology	Recipient Artery-Nerve	Follow-up (months)	Second Operation	Light Sensation	Deep pressure	Complications
1	M	20	9*16	5	Marjolin's ulcer	ATA-PTN	53	-	+	+	-
2	M	23	14*19	4	Wheel injury	ATA-PTN	36	Debulking at the first year	+	+	-
3	M	64	12*15	3	Marjolin's ulcer	PTA-PTN	30	Contour revision at first year	-	+	-
4	F	16	11*18	5	Wheel injury	ATA-PTN	38	-	+	+	-
5	M	38	10*13	4	Wheel injury	PTA-MPN	33	-	+	+	-
6	M	51	12*17	5	Wheel injury	ATA-PTN	52	-	-	+	Minor abrasion
7	M	60	10*14	4	Skin cancer	PTA-MPN	52	-	-	+	Minor abrasion
8	F	42	13*15	4	Burn contracture	PTA-MPN	24	-	+	+	-

ATA: Anterior tibial artery, PTA: Posterior tibial artery, PTN: Posterior tibial nerve, MPN: Medial plantar nerve.

lected perforator, all perforators are clamped with microvascular clips to evaluate flap circulation. If there is no problem, the other perforators are transected. Flap circulation is checked, and the selected perforator is followed to the main pedicle by intramuscular or intermuscular dissection. A few muscle fibers can be taken with the perforators to prevent vessel injury spasm. The perforator dissection is completed, and the descending branch or transverse branch of the lateral circumflex femoral artery is isolated in the intermuscular space as well as in the nerve supplying the vastus lateralis muscle. The pedicle is dissected until a desirable pedicle length is obtained. Because the flap is elevated as a sensate flap, the incision is extended a few centimeters from the superolateral border of the flap proximally, and the lateral femoral cutaneous nerve is found and included in the flap.

The largest flap used was 14x19 cm. Sensory nerve coaptation to the posterior tibial and medial plantar nerve in an end-to-side fashion was performed in all cases. Also all but one of the flaps were thinned peroperatively. The donor flap areas were closed directly in three patients, with split thickness skin grafts in three others, and perforator based v-y advancement flaps in two patients. Early ambulation was encouraged in all patients. The postoperative rehabilitation involved extensive education of the patients in foot and flap care with serial follow-ups.

RESULTS

Of the eight free flaps that were performed, all survived, and the flaps presented good contours. Only one flap required a secondary debulking procedure at the end of the first year. Protective footwear was offered for at least six months. Self-resolving minor abrasions were observed in two flaps at the end of the first year. Partial weight-bearing was allowed at the fourth week and full weight-bearing at the eighth week. The time period until full ambulation averaged three months.

All patients were sensitive to deep pressure, although only five were able to recognize light touch. Static pedograms demonstrated abnormal pressure distribution on the flap surfaces of only one patient, and he was operated on for contour revision of the bone surface.

The reconstruction was stable in all cases throughout the follow-up period (24-53 months), and the patients all walk normally wearing custom-made (n=3) and normal footwear with self-made adaptations (n=5).

CASE 1

A 20-year-old man with Marjolin's ulcer on the heel was treated with an anterolateral thigh flap. The size of the flap was 9x16 cm with a vascular pedicle of 6.5 cm (Figure 1). End-to-side anastomoses to the anterior tibial artery and coaptation to the posterior tibial nerve were performed. The donor site was closed with a skin graft, and the postoperative course was uneventful. Gradual loading on the flap was started at the fourth week. The follow-up period was 53 months (Figure 2). The patient had protective sensation and was aware of deep pressure sensation. The Semmes-Weinstein monofilament test revealed normal light touch sensation.

CASE 2

A 23-year-old man with a heel defect was treated with a free anterolateral thigh flap. The size of the flap was 14x19 cm with a vascular pedicle of 6 cm (Figure 3). The arterial pedicle was anastomosed to the anterior tibial artery in an end-to-end manner. Nerve coaptation was performed to the posterior tibialis nerve, and the donor site was closed with a split thickness skin graft. A secondary debulking procedure was performed at the postoperative first year. The follow-up period was 36 months , and the patient had both deep and light touch sensation (Figure 4).

CASE 3

A 64-year-old man with Marjolin's ulcer on the left heel was treated with a free anterolateral thigh flap. The size of the flap was 12x15 cm with a 7 cm vascular pedicle (Figure 5). End-to-side anastomoses were performed between the pedicle of the flap and the posterior tibial vessels. Nerve coaptation to the posterior tibialis nerve was performed. The donor site was closed with a split thickness skin graft, and the postoperative follow-up was uneventful. At the postoperative first year, a static pedogram was performed and abnormal pressure distribution on the flap surface was observed. The patient was operated on for the contour revision of the bony surface at the first year, and after the 30-month follow-up period no re-

FIGURE 1: Upper left: Marjolin's ulcer on the scar tissue; upper right: the defect after wide resection of the ulcer; lower left: the flap demonstrating the nerve, artery, and vein; lower right: early postoperative view of the flap.

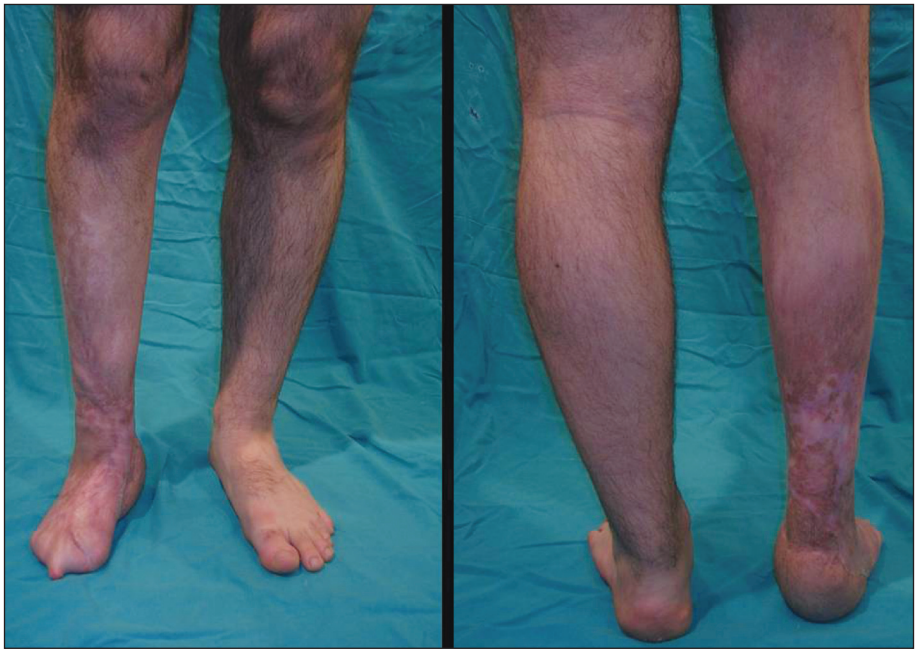

FIGURE 2: Late postoperative views of the flap.

FIGURE 3: Upper: preoperative view of the chronic wound with trophic changes; lower: the flap demonstrating the nerve, artery, and accompanying veins of the flap.

currences were observed (Figure 6). The patient had deep sensation; however, light touch sensation was not demonstrated.

DISCUSSION

The skin of both the heel and sole of the foot has particular histologic characteristics presenting a thick epidermis and dermis with a very thin subcutaneous tissue and very sound adherences between the dermis and the muscle below. The main goal of reconstruction of the heel is to provide a durable coverage with a normal appearance and allow the patient to walk properly and wear normal shoes.[1]

The ideal technique for weight-bearing plantar reconstruction should meet such conditions as a durable and comfortable surface, solid anchoring to deep tissue for resistance to shear force, and adequate protective sensation.[9] The plantar area has specific anatomical and biomechanical characteristics. The skin in this area is the thicker than other parts of the body. Firm attachment of the strands of fibrous tissue aids in resisting torsion, and the plantar area is required for withstanding weight-bearing pressure and shearing force.[2]

The treatment choice depends on the site, dimensions, and cause of the defect.[5] Different options for reconstruction have been described throughout history, such as the reverse sural flap, the instep flap, the lateral supramalleolar flap, the lateral calcaneal flap, the dorsalis pedis flap, the flexor digitorum brevis muscle flap, and different options for free flaps like fasciocutaneous and muscle flaps with skin grafts.[1,4,6-8,10-17] As a general reconstructive principle,

FIGURE 4: Late postoperative views of the flap.

FIGURE 5: Upper left: preoperative view of the ulcer; upper right: the defect after wide resection of the ulcer; lower left: flap dissection solely on the pedicle; lower right: the thin flap.

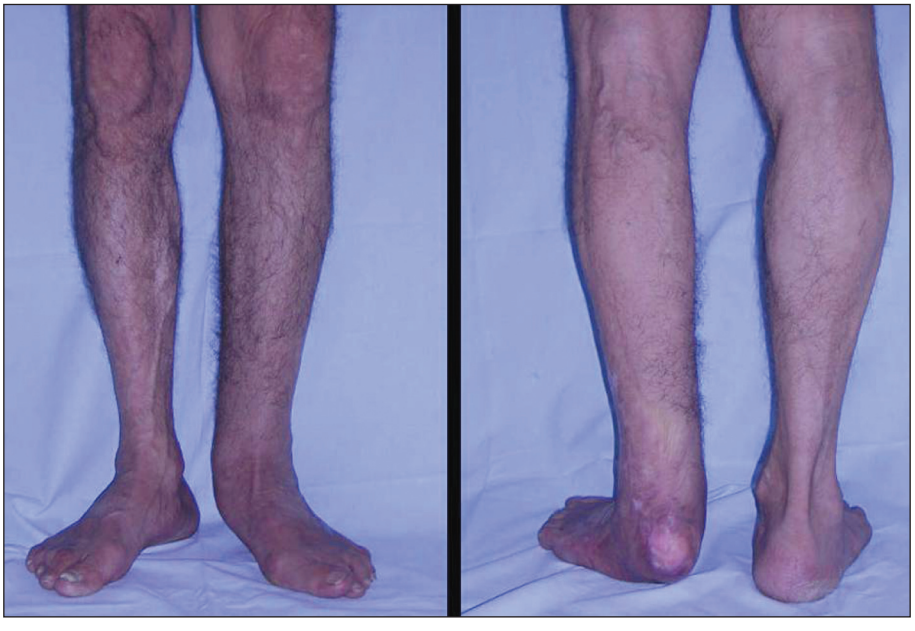

FIGURE 6: Late postoperative views of the flap.

tissue defects should be repaired with like tissues. Skin grafts do not provide the characteristics of heel and sole of the foot, and they are sensitive to trauma, pressure and shear force. Although locoregional flaps are very useful for reconstructing soft-tissue defects in the heel and sole of the foot, the complexity of the defect and the scarcity in the amount of tissue available may prevent the use of these flaps.

The limited tissue supply, difficulty of flap dissection and transferring the tissue from trauma zone are disadvantages of these flaps. A more sophisticated reconstruction alternative is usually required for this region. Thanks to the development of microsurgical procedures and of a better understanding of lower limb neurophysiological characteristics and their importance for long-lasting results, foot reconstruction has attracted increased interest in the past decade; currently, large-area foot reconstruction is attempted mainly by means of free tissue transfer.[18]

Cutaneous free flaps seem more reasonable in cases where there is minimal disruption of the underlying structures. Advocates of cutaneous free flaps suggest that cutaneous flaps intrinsically resist shearing forces.[19]

The anterolateral thigh flap is reliable for extremity reconstruction, and the functional impairment of the donor thigh is minimal.[5,20,21] The flap has many advantages: a relatively constant vascular pedicle, wide and large skin territory, which is innervated when necessary, and a concealed donor site.[22] The fascia component of the flap can withstand pressure and shearing force on the sole.[2,23] A thin and pliable coverage supplied by this flap is necessary for flexible joint motion and normal footwear.[9] Because of this, secondary debulking procedures are not required. Despite all these advantages of the anterolateral thigh flap, one case in our study required debulking procedure due to the planning of the flap.

However, the issue of reinnervation of the flaps in sole and heel reconstruction is controversial. Although neurosensorial skin flaps provide better sensibility, the overall results are not superior to skin grafted muscle flaps, as indicated by many authors.[17] Kuran et al. demonstrated that the restoration of sensation provided the advantages of the patient being able to return to daily activities in a shorter time without the necessity of wearing a protective shoe. However, in the long run, patients who have had reconstructions with nonsensate flaps reported no difficulties with their daily routines compared to the sensate flap group.[4] Although there was no difference in sensate and nonsensate flaps in long term follow-up in the study of Kuran et al.; we observed that the sensate anterolateral thigh flap has advantages. However better evaluation can be achieved by increasing the number of cases and long term follow-up results. Sekido et al. who were the first to use an anterolateral thigh flap for plantar reconstruction have suggested that sensory reconstruction plays a significant role in avoiding ulceration and obtaining normal gait in the reconstruction of the weight-bearing area of the sole.[2] With their large series of anterolateral thigh flaps, Hong et al. demonstrated good results both with and without sensory reinnervation. Out of 69 patients, 17 underwent sensory nerve coaptation. A positive response was noted in 76 percent of the sensate flap group and 20 percent of the nonsensate flap group by three months. This was a statistically significant difference. With nerve coaptation, sensation can be reestablished as early as three months postoperatively.[9] The use of nerve coaptation is suggested in young, highly motivated patients to improve stability of the flap, with an earlier return to load capacity and a full recovery to normal activity.[18] The same functional results were obtained in our patients, and light touch was not returned in three of the patients, who were the oldest in our group. If the conditions are suitable, nerve coaptation should be preferred.

CONCLUSION

The innervated anterolateral thigh flap was preferred in this study because the advantages were achieved earlier than with the noninnervated flaps. The results favored nerve coaptation as demonstrated in the literature. Nerve coaptation is preferred in selected patients, and protective footwear was required in all cases. The flap fulfilled all the prerequisites of the reconstruction of this specialized region. It is the flap of choice, with various advantages and limited morbidity, for surgeons who are dealing with reconstruction of complex defects of the heel and plantar area.

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Conflict of Interest

No conflicts of interest between the authors and / or family members of the scientific and medical committee members or members of the potential conflicts of interest, counseling, expertise, working conditions, share holding and similar situations in any firm.

Authorship Contributions

Idea/Concept: *Serkan Yıldırım;* ***Design:*** *Gaye Taylan Filinte;* ***Control/Supervision:*** *Tayfun Aköz;* ***Data Collection and/or Processing:*** *Çağla Çiçek;* ***Analysis and/or Interpretation:*** *Gaye Taylan Filinte;* ***Literature Review:*** *Çağla Çiçek;* ***Writing the Article:*** *Çağla Çiçek;* ***Critical Review:*** *Çağla Çiçek;* ***References and Fundings:*** *Çağla Çiçek;* ***Materials:*** *Çağla Çiçek.*

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