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Lower extremity soft tissue reconstruction with free flap based on subscapular artery

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Objective: The purpose of our study was to evaluate the results of the reconstruction of the lower extremity defects with free flaps based on the subscapular artery.

Methods: Between January, 1998 and December, 2008, 51 patients (mean age 26 years; 16 female and 35 male) presenting with a lower extremity defect underwent a reconstructive surgery with flaps based on the subscapular vascular system. Thirty-seven percent of the defects were located in the crus, 19% in the sole, 16% in the heel, and 14% in the dorsum of the foot. Eighty and a half percent of the patients had traffic-accident-related and 13.5% had burn-related tissue defects.

Results: Fifty-three percent of the patients presenting with lower extremity defects underwent reconstruction with latissimus dorsi muscle flaps, 21% with free serratus muscle and/or fascia flaps, 14% with free parascapular fasciocutaneous flaps, and 12% with free combined latissimus muscle and serratus muscle and/or fascia flaps. Anastomoses of 80% of the patients were performed on their posterior tibial artery and accompanying veins and/or foot dorsal veins. End-to-end anastomosis was performed on 14 patients, while 35 patients received end-to-side anastomosis. Six patients were treated with cross free flaps, of which 4 received cross latissimus, 1 cross serratus, and 1 cross combined serratus and latissimus flaps. End-to-side anastomoses were performed on these patients on the cross-leg tibialis posterior artery. The cross-leg anastomosis was freed 4 weeks later. In the early period, venous occlusion was observed in 4 patients and arterial and venous occlusion was present in 1 patient. New anastomoses were performed in these patients. Partial necrosis was observed in 2 patients. The average follow-up period was 61 months. Pressure-related late ulcerative lesions developed in 4 patients. The lesions of these patients were repaired by debridement and primary suturing or partial thickness skin grafts.

Conclusion: The subscapular vascular system based flaps have an optimal vascularity once they are prepared with adequate pedicles, causing minimal donor site morbidity. These flaps are a safe and effective alternative in lower extremity reconstruction. On the other hand, in the absence of appropriate recipient vessels, single or combined cross-leg free flaps may provide successful repair.

Key words: Free flaps; lower extremity defects; subcapulary artery.

The use of free flaps are accepted as the standard reconstruction method in severe defects of the lower extremity.[1,2] The procedure's success is closely related to selecting the appropriate donor flap and the microsurgery experience, as well as the presence of the appropriate recipient vessels.[2] Free flaps in the lower extremity may be necessary for high energy injuries, open fractures of the middle and distal

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one-third tibia, radiation injuries, osteomyelitis, and large, soft tissue defect exposing bone tissue after radical resections of the tumors.[3,4]

Despite the increasing knowledge of the anatomy and physiology of flaps and technical progresses, loss of flap is still observed in free tissue transfers for lower extremity reconstruction. However, partial or total loss of flap negatively affects both the postoperative course and long term results.

The subscapular vascular system supplies blood to a number of structures. This gives the opportunity to produce several flaps from this region. When the circumflex scapular vascular system is combined with the thoracodorsal artery, latissimus dorsi muscle, serratus muscle and/or fascia flap, and scapular tissues can be prepared with a single vascular pedicle.[5,6] Versatility of these flaps yield any combination of subcutaneous tissue, fascia, muscle and bone, enabling the repair of large tissue defects.[7]

Godina published his experiences with microsurgical reconstruction of complex extremity injuries in 1986. He reported that lower extremity reconstructions resulted in success when they are done within the first 72 hours after the injury. The highest incidence for infection and loss of flap were found in reconstructions performed between 3 days to 3 months after the injury.[8]

Acute and chronic post-traumatic defects were the most common indication for lower extremity reconstruction with free flaps. Combined flaps are an alternative for the closure of large defects in a single stage surgery. While sometimes even one recipient vessel can not be found in patients with large defects, the transfer of multiple flaps may further complicate the procedure.[9,10]

Cross-leg free flaps may be used in severe soft tissue defects, where transfer of a simple free flap is not possible. In cross-leg free flaps the vascular pedicle of the flap is anastomozed to the vessels of the healthy opposite leg. After the integration and vascularization of the flap, with local recipient tissues, the flap is separated from the opposite leg. Cross-leg free flap is the last option in free flap reconstruction of the leg defect.[11]

To our knowledge, our series is the largest series on a subscapularis system based free flap reconstruction. The purpose of our retrospective study is to report our experience with flaps based on the subscapular artery and to evaluate the applicability and reliability of these flaps in 51 patients with defects in the distal lower extremity.

Patients and methods

Between January, 1998 and December, 2008, 51 patients (mean age 26 years [3-65 years]; 16 female and 35 male) with lower extremity defects were treated with free flap transfer based on the subscapular artery, in Department of Plastic and Reconstructive Surgery, Sisli Etfal Training and Research Hospital, Istanbul (Table 1). The patient's files were reviewed to acquire demographic data, specify the etiology and anatomical localization of the defects. The flap types chosen for the treatment, recipient vessels, type of anastomosis, surgery time, recipient region, general complications and the ultimate walking ability, were recorded. The recipient site complications were identified as hematoma, seroma, infection, opening of the wound and partial or full-flap necrosis. The time up until the second exploration, the fate of the flap, and, the degree of the necrosis, were noted for the evaluation of the flaps that required revision for the postoperative thrombosis of the anastomosis. Furthermore, smoking, peripheral artery disease, diabetes and presence of a fracture were all questioned. An angiography was performed when there was a peripheral artery

Table 1. Variations of the patients according to their ages.

Age	Number	Percent (%)
0-5	4	7.5
6-10	7	13.5
11-15	5	10.0
16-20	6	12.0
21-25	6	12.0
26-30	5	10.0
31-35	3	6.0
36-40	2	4.0
41-45	4	7.5
46-50	4	7.5
51-55	-	-
56-60	2	4.0
61-65	3	6.0
Total	51	100.0

disease or when the distal lower extremity pulses were absent upon physical examination.

Flap selection was made after the analysis of the defect, independent of its etiology. The order of surgical operations in free flap transfer was: radical debridement, dissection of recipient vessels, preparation and removal of free flap tissue, microsurgical anastomosis and adaptation of the free flap tissue to the defect. Depending on the number and quality of the patent vessels, the type of the defect and the pedicle length, end-to-end or end-to-side anastomosis was performed. Papaverine was applied locally in order to prevent the spasm of the flap pedicle. The flap bed was closed over a suction drain. After the surgery, the patients were intravenously given Dextran 40 (Rheomacrodex-10 B, Braun Medical) at 50 ml/hour for 5 days and low molecular weight heparin at prophylactic dose. A follow-up of the flaps was done by clinical observation (capillary refilling, congestion, flap color and temperature) and Doppler sonography.

Results

The demographic data of the patients is presented in Table 1. Forty-one percent of the patients were in the pediatric group (between the ages of 3-18). Nine of them were female and 12 were male. The etiological factor in 18 of the pediatric patients (86%) was determined as a traffic accident. Nineteen of the defects were located in the leg, 10 in the sole, 8 in the heel, 7 in the dorsal foot, and 4 in the malleolus. Three defects were large enough to include both the crus and the dorsal foot (Table 2). The defect was on the right side in 26 cases, and on the left side in 25. The etiology of the defect was a traffic accident in 41 patients (80.5%), a burn in 7 (13.5%), a crush injury in 1, a malignant melanoma in 1, and a collagen tissue disease in 1. The size of the defects varied between 4x3 cm and 18x20 cm. Nine patients (18%) were treated with early reconstruction (first 72 hours), 35 patients (68%) with delayed reconstruction (3 days - 3 months), and 7 patients (14%) with late reconstruction (after 3 months).

Three patients (6%) had a peripheral artery disease and 3 patients (6%) had diabetes. All of the patients with peripheral artery disease were smokers. Eleven patients (22%) smoked until the time of trauma. Twenty-one patients (41%) had Gustilo type 3 B fractures.

Twenty-seven of the patients (53%) were treated with free latissimus dorsi muscle flap, 11 (21%) of them with free serratus muscle or fascia flap, 7 (14%) with free parascapular fasciocutaneous flap, and 6 (12%) with free combined latissimus muscle and serratus muscle and/or fascia flap (Table 2). Seven patients had defects on the dorsum of the foot, of which 6 of them were treated with latissimus dorsi muscle flap and 1 with parascapular fasciacutaneous flap. Among 10 patients with a sole defect, 8 were reconstructed with serratus anterior muscle (Fig. 1)

Table 2. Etiology related to localisations of the defects and variations of the harvested flaps.

	Etiology (n)	%	Flap type (n)	%
Crus	Traffic accident (16)	31	Latissimus dorsi (15)	29
	Burn (2)	4	Serratus anterior (1)	2
	Crush injury (1)	2	Latissimus dorsi + Serratus anterior (3)	6
Dorsum of the foot	Traffic accident (7)	14	Parascapular (1)	2
			Latissimus dorsi (6)	12
Malleolus	Traffic accident (3)	6	Parascapular (4)	8
	Malign melanoma (1)	2		
Heel	Traffic accident (8)	15	Latissimus dorsi (6)	12
			Serratus anterior (2)	4
Plantar surface of the foot	Burn (5)	10	Parascapular (2)	4
	Traffic accident (4)	8	Serratus anterior (8)	15
	Collagen tissue disease (1)	2		
Crus and dorsum of the foot	Traffic accident (3)	6	Latissimus dorsi + Serratus anterior (3)	6
Total	51	100	51	100

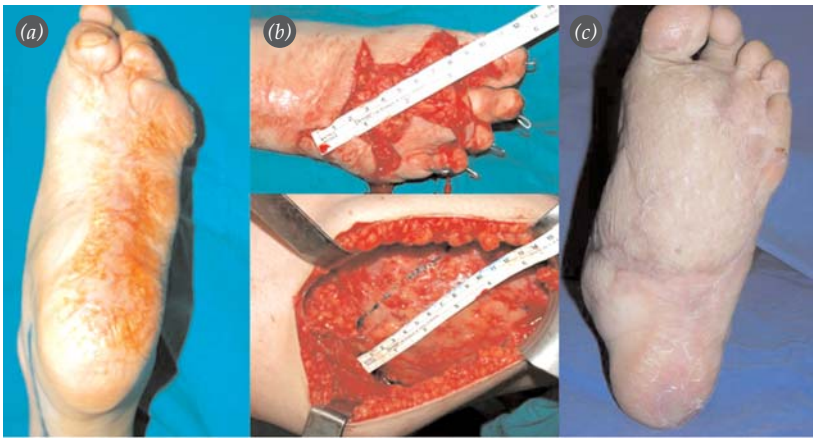

Fig. 1. **(a)** A serious burn contracture was seen on the plantar surface of the foot. **(b)** Contracture bands released and K fixation were used and free serratus anterior flap was harvested and applied to defect on the plantar surface of the foot. **(c)** Late postoperative view of the patient. [Color figure can be viewed in the online issue, which is available at www.aott.org.tr]

and 2 with parascapular fasciacutaneous flap. Of the 19 patients with the leg defect, 15 were reconstructed with latissimus dorsi muscle, while 3 of them were treated with combined latissimus dorsi and serratus anterior muscle flap. All of the malleolary defects were reconstructed with parascapular fasciocutaneous flap, while 6 of the heel defects were treated with latissimus dorsi, and 2 with serratus anterior muscle flaps and partial thickness skin graft. Three patients with large defects in the dorsal foot and crus were reconstructed with combined latissimus dorsi and serratus anterior flap (Table 2).

The posterior tibial artery and the adjacent vein or superficial veins were used for anastomosis in 41 patients and the tibialis anterior and the adjacent veins in 10 patients. Anastomoses were performed in the proximal part of the injured site. Two patients had a vein graft in order to lengthen the pedicle. While an end-to-side anastomosis was performed in 37 patients, end-to-end anastomoses were carried out in the remaining 14. End-to-end anastomoses were performed on the veins. While 45 of these anastomoses were performed in the recipient veins of the same leg, in 6 patients the cross-leg posterior tibial artery was used for the anastomosis, as there was no appropriate vein with enough blood flow and of the same caliber on the same leg.

Among the patients, who were treated with a cross-leg anastomosis, 3 were female and 3 were male, with an average age of 25.8 years (18-36 years). Four of the patients had a tissue defect after a traffic accident, while 2 had it as a burn sequela. The latissimus dorsi muscle flap was used in 4 patients, serratus anterior muscle and fascia flap in 1, and combined serratus anterior muscle and latissimus dorsi muscle flap in 1. All anastomoses were performed as end-to-side on the posterior tibial artery (Fig. 2). Of the 6 patients, reconstructed with combined flap, 4 were male and 2 were female. They had an average age of 27.3 years (5-39 years). All of the patients had the defect after a traffic accident. Both the latissimus dorsi muscle and the serratus anterior muscle flaps were used in all patients. All anastomoses were done on the posterior tibial artery. Three anastomoses were performed as end-to-end, whereas 3 anastomoses were carried out as side-to-end (Fig. 3).

Out of the 44 flaps, prepared as a muscle and/or fascia flap, the skin island was included in 10 for monitorization. Partial thickness skin flaps were applied on these flaps. The graft was loosely sutured only to adapt to the flap, in order to avoid the tension formed due to the edema in the postoperative period.

The average operation duration was 6 hours and 11 minutes (between 5 hours 20 minutes and 7 hours 25 minutes). No relation could be found in the operation duration, flap type and complications. On the other hand, it was observed that operation duration of combined flaps were longer.

Postoperative anastomosis complication was not seen in 45 free flap transfers (90%). A vascular failure, requiring re-exploration, was seen in 5 latissimus dorsi muscle-skin flaps. Venous occlusion was detected in 4 patients, while arterial and venous occlusion was seen in 1 patient. These patients required a revision of the anastomosis.

While total necrosis was not observed in the flaps, partial loss of flap was observed in 2 cases

Fig. 2. **(a)** Cross free latissimus dorsi muscle flap were planned due to arterial insufficiency in the ipsilateral leg in patients 19 years old. **(b)** Cross free latissimus dorsi muscle flap was adopted to reconstruct the defect due to burn contracture on the crus. **(c, d)** Postoperative view of the patient anteriorly and laterally. [Color figure can be viewed in the online issue, which is available at www.aott.org.tr]

(4%), in which the defect was reconstructed without the need of a new flap. No significant correlation could be seen between partial flap necrosis and the flap type, risk factors and comorbidity. In the late period, the necroses were debrided and treated with partial thickness graft.

The patient, diagnosed with an arterial and venous occlusion, had a history of peripheral artery disease and smoking, and a partial necrosis occurred despite the revision. On this patient, an end-to-end anastomosis was performed on the anterior tibial artery. One patient, who had a venous occlusion, was in the pediatric group, one patient had diabetes and another had a history of smoking. Partial necrosis only developed in the diabetic patient. Among these patients, 3 had a side-to-end anastomosis on the posterior tibial artery and 1 had an end-to-end anastomosis on the anterior tibial artery. Partial necrosis was observed in the patient that had an end-to-end anastomosis to the anterior tibial artery. One of the patients that required a revision was treated in the acute period, while 4 of them were treated in the early period. Cases of partial necrosis were in the early period group patients. Three of the patients, requiring revision, had a Gustilo Type 3 B fracture (Table 3). Two of the 11 patients (18%), who were smokers, needed revision. Eighty-eight percent of all flaps did not have recipient site complications. Complications, such as superficial infection, hematoma and seroma were left to secondary healing. There were no persistent or recurrent osteomyelitis and the time of adaptation of the flaps to the defects had no effect on the healing of the wound.

Seven patients were detected to have minimal donor site morbidity (Table 4). The patients were followed for an average of 61 months (range: 8 to 118 months). It was observed that all of the patients could walk. Four patients had pressure sores: 3 on the heel and 1 on the sole. The patients' lesions were treated either with a debridement and a primary repair or a partial thickness skin graft.

Discussion

Microsurgery operations in extremity reconstructions have been successfully performed for about 30 years. In recent years, free flap transfer has become the first choice in lower extremity injuries.[2,5] The

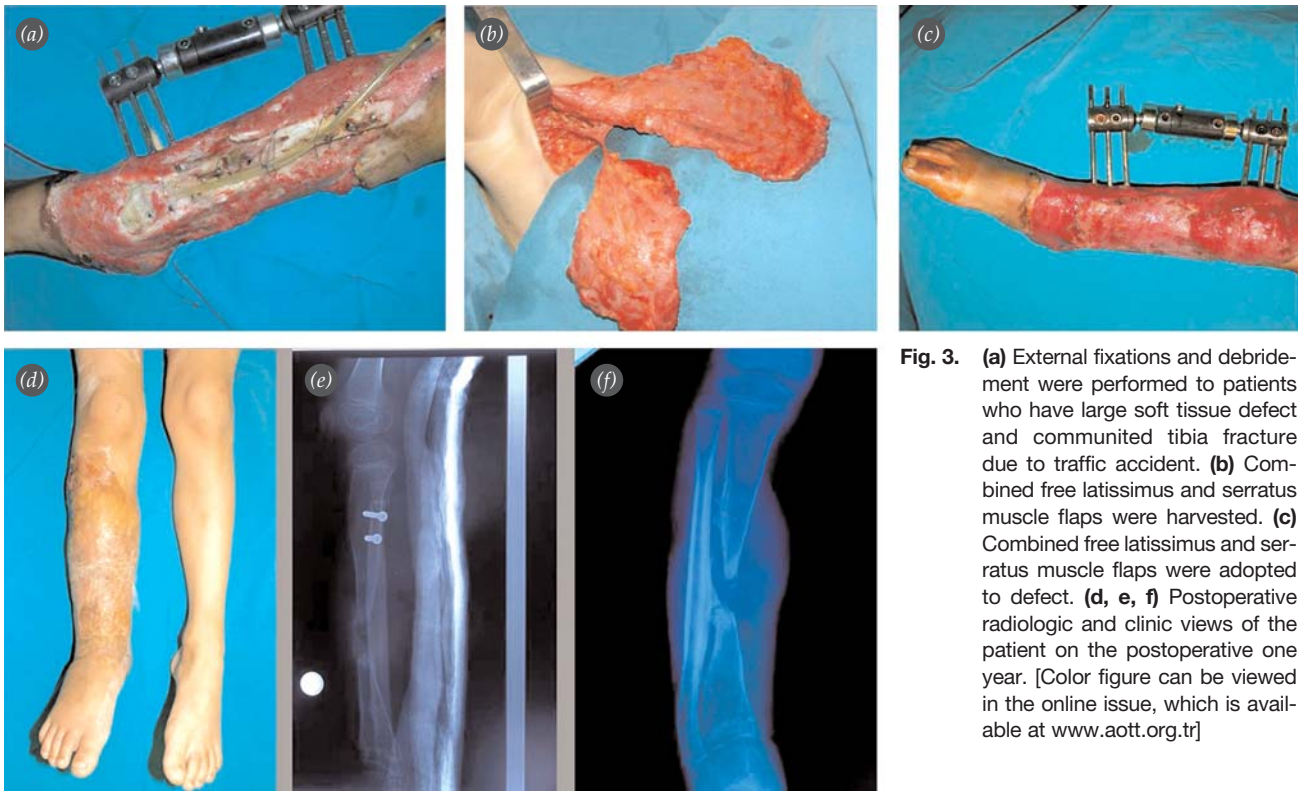

Fig. 3. **(a)** External fixations and debridement were performed to patients who have large soft tissue defect and communited tibia fracture due to traffic accident. **(b)** Combined free latissimus and serratus muscle flaps were harvested. **(c)** Combined free latissimus and serratus muscle flaps were adopted to defect. **(d, e, f)** Postoperative radiologic and clinic views of the patient on the postoperative one year. [Color figure can be viewed in the online issue, which is available at www.aott.org.tr]

most common indication for this method is acute and chronic post-traumatic defects. Similar to the literature, 80.5% of the injuries in our study were due to traffic accidents. Large defects in distal and middle one-third of the crus may also require a free flap transfer.[2] All of the defects in this study were located in the middle-lower one third of the leg or in the foot.

Lower extremity microsurgical procedures are being performed successfully and safely even in very young and old patients.[2,12] In our study, the subjects' ages ranged from 3 to 65 years old. Twenty-one percent were under 10 years old, while 10% of them were above 50. A venous occlusion was observed in the early period in one patient under 10 years old and in another patient above 50, but the flap survived after the revision of anastomoses.

Free flap selection for lower extremity construction depends on various factors. Type and volume of the lacking tissues and the surface of the injured tissue are the most significant predictive factors. The tissues to be transferred are selected depending on features, such as donor site morbidity, recipient site requirement, vascular pedicle length and the one that provides the most appropriate aesthetic result.[2]

Flaps, based on subscapular artery system, provide the opportunity to reconstruct various tissue defects. Free muscle flaps for complex defects in the ankle and open fractures in the distal one-third tibia are an appropriate treatment choice in comminuted

Table 3. Demographic data of the revised flap and types of the harvested flaps.

Complications	n (%)	Age	Sex	Smoking	PDH	Diabetes	Muscle flaps	Fasciocutaneous flap
Partial flap loss	2 (4)	52 (42-62)	M	1	1	1	2	-
Vascular thrombosis	5 (10)	40 (4-62)	2F/3M	2	1	1	5	-
Flap salvage	5 (10)	40 (4-62)	2F/3M	2	1	1	5	-

fractures, loss of tissue in large volumes and the presence of dead space.[4] If it is not a comminuted fracture, the tissue defect is minimal, and there is no dead space, allowing for fasciocutaneous flaps. The scapular, parascapular, radial forearm, lateral arm, groin and anterolateral thigh flaps have a better aesthetic than the muscle and muscle-skin flaps. Since fasciocutaneous flaps are not large, patients can wear normal shoes when the flaps are applied on the defects on the distal one-third of the tibia, ankle and the dorsum of the foot.[4] On the other hand, some publications report that there is no significant difference between the muscle flaps and fasciocutaneous flaps, in terms of consolidation and infection on the wounded site.[13] In this study, while muscle flaps were preferred in large injuries with fractures in crus and the dorsal foot, fasciocutaneous flaps were preferred in smaller defects around the malleolus. Muscle flaps and skin grafts are preferred for large defects, including those on the plantar surface and the heel, while the serratus anterior muscle flaps are preferred for large defects that result from burn contractures on the sole.[14] The use of non-sensitive flaps in the reconstruction of the ankle and sole defects will obviously delay the return to daily activities. However, good results may be obtained in these patients with appropriate foot care and shoe wear.

When a reconstructed sole and a healthy sole were compared, sensitive and non-sensitive flaps revealed similar results in the pedogram analysis.[8] In our study, muscle flaps and skin grafts were preferred for the reconstruction of the ankle and the sole. Four of the patients had ulcerative lesions in the late period, and the defect was covered with skin graft after the debridement.

The subscapular artery, branching from the axillary artery, can be qualified as a relatively large artery with a caliber of 2.5-4 millimeters.[9] After the subscapular artery arises from the circumflex scapular artery, it continues as the thoracodorsal artery, which supplies the latissimus dorsi muscle. The circumflex scapular artery has horizontal and vertical branches that supply the scapular and parascapular artery. About 5.5 centimeters after the origin of the thoracodorsal artery, a branch separates and travels to the serratus anterior muscle.[7,8,15,16] The thoracodorsal artery leads to an angular branch of the scapula, just before entering the latissimus. This branch enables the preparation of the scapula as a segment. The dividing of the artery to the central and the peripheral branches, after entering the latissimus muscle, enables the splitting of this muscle flap. The thoracodorsal artery is accompanied by one vein, while the circumflex scapular artery is accompanied by two veins. With the vascularization of the subscapulary system, different flaps can be prepared one by one or by being combined.[9,16,17] The repair of large, wide or composite defects usually requires combined flaps that include two or more flaps.

Table 4. Postoperative complications (%).

Complications	n	%
Seroma	2	4
Hematoma	4	8
Infection	3	6
Scar	2	4
Wound healing problem	2	4
Partial necrosis	2	4
Total	15	30

The transfer of the combined flap of the latissimus dorsi and the serratus anterior, using one vascular vessel, was described by Harii et al. in the early 1980s.[17,18] In this study, we reported 51 patients who underwent a treatment with different flaps, based on the subscapulary system, in the repair of the lower extremity defects. The latissimus dorsi flap was used in 27 patients, the serratus muscle and/or fascia flap in 11, and the parascapular fasciocutaneous flap in 7 patients.

However, the combined flap of the latissimus dorsi muscle and the serratus anterior muscle and/or fascia flap were used in 6 patients with large defects. In our literature review, we have not come across any detailed series, where lower extremity construction was performed with free flaps, based on subscapular artery.

In Godina's milestone article, it was reported that the rate of failure in free tissue transfers in delayed reconstruction (between 3 days to 3 months) was 12%, while the rate of failure in late reconstructions (more than 3 months) was 9.5%. As for our study,

early reconstruction was performed on 9 patients (18%), delayed on 35 (68%) and late reconstruction on 7 patients (14%).[8] One of the patients, requiring a revision, was in the early reconstruction group, and 4, in the delayed reconstruction group. In the late reconstruction group, patients did not have any vascular problems.

If the transfer is in the lower extremity, selection of the recipient vessel is important for the success of the reconstruction.[19] At the same time, there is no consensus on which vessel to use. Two significant factors in the choice of the recipient vessel are the site of injury and the circulation of the lower extremity.[19] Using the anterior tibial artery is easier when compared to the posterior tibial artery. However, it is usually insufficient in the case of an end-to-side anastomosis. The posterior tibial artery is a better alternative for anastomosis, with its wider caliber and higher flow. However, an end-to-end anastomosis with this main vessel may impair the circulation of the leg. In our series, the posterior tibialis artery was chosen for anastomosis in 41 patients. While an end-to-side anastomosis was performed in 35 patients, an end-to-end anastomosis was performed in 14. Prior to the end-to-end anastomosis, circulation of the leg was checked by putting a temporary clamp in the artery. All of the vein anastomoses were performed end-to-end.

The theory of the injury zone is the inflammatory response of the soft tissue along the injury in traumatic extremity, which results in perivascular changes of the blood vessels. These changes, such as vascular fragility increase in the perivascular scar tissue, are raising the rate of loss based on a microvascular thrombosis.[2] There are some studies which assert that anastomosis should be done on the healthy tissues far from this region.[2] Although anastomoses were performed outside the injury region in all of the cases, a venous occlusion was observed in 4 patients, and an arterial and arterial and venous occlusion was seen in only 1 patient. When the occlusion was noticed in the early period, the anastomosis was repeated. In 2 cases, the patients recovered with no problems, except from partial necrosis. Some surgeons emphasize the necessity of using vein graft in order to reach the healthy recipient vascular vessels.[2,11] In the 2 cases reported here, the healthy region was reached by using a vein graft and these cases recovered without problem. There are also cases where there are not enough recipient tissues adjacent to the defected site. In these cases, anastomosis might not be successful, even by using vein graft. In such situations, it could be useful to use cross-leg free flaps. Taylor et al. defined the use of cross-leg free flaps, first in 1979.[2] This technique consisted of anastomosing the vessels of a free flap to the vessels of the opposite healthy leg. After the constitution of the local circulation in the defect area, the cross-leg anastomisis is separated and the free flap survives with the local vascular supply. This flap type is the last chance for the reconstruction with a free flap.

In our study, cross-leg free flaps were used in 6 patients and 4-6 months after the operations, cross-leg anastomoses were separated. The latissimus dorsi muscle was used in 4 cases, while serratus anterior muscle was used in 1. A combined flap of serratus anterior and latissimus dorsi muscles was used in 1 patient. The patients did not have any problem in the follow-up.

In the cross-leg free flap transfers, end-to-side anastomosis is usually preferred; whereas, in risky cases, end-to-end anastomosis might be obligatory.[2,20,21] Since a main artery of the healthy leg is sacrificed in end-to-end anastomosis, some problems related to the decrease in the blood flow might occur in this leg in due course. To prevent such problems, though, it has been suggested to perform a vein graft[2] and an artery graft[22,23] between the recipient site's proximal and distal ends, following the separation of the cross-leg free flap.[2] To compensate the decreased blood flow of the recipient artery, the thoracodorsal artery was taken with its bifurcation and two anastomoses were performed by Topalan.[21] Anastomoses of the cross-leg free flaps here were end-to-side, thus, the blood flow of the healthy leg was not affected. In addition, the patients had no problems with the flap's survival. No risk factor for a microvascular complication was detected. Among the 5 patients with vascular thrombosis, 1 was under 5 and 4 were above 40 years old. Two of these patients were smokers, one of them had peripheral artery disease and one had diabetes. In the 2 patients with venous occlusion, risk factors, such as smoking, peripheral artery disease or diabetes could not be found.

The subscapular vascular system based flaps have an optimal vascularity once they are prepared with adequate pedicles, causing minimal donor site morbidity. These flaps are a safe and effective alternative in the lower extremity reconstruction. It provides a successful repair with single or combined cross-leg free flaps, in cases with no appropriate recipient vessels for anastomosis.

Conflicts of Interest: No conflicts declared.

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