



Differences between the Upper Extremity and the Lower Extremity in Reconstruction Using an Anterolateral Thigh Perforator Flap

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Background: While reconstruction of soft tissue defects is the common purpose, surgical reconstructions of upper extremities and lower extremities have different goals in terms of functional and aesthetic outcomes. The purpose of the current study was to compare and analyze differences between reconstructions of upper extremities and lower extremities using an anterolateral thigh (ALT) flap.

Methods: We analyzed 74 patients who underwent reconstructions of upper extremities and lower extremities using an ALT flap from October 2006 to August 2012 (upper extremities, 45 cases; lower extremities, 29 cases). The study focused on the statistical analysis of patient satisfaction according to the donor site of the ALT flap and the timing of a debulking procedure.

Results: On the choice of donor site, in the upper extremity reconstruction, flap elevation from the opposite side of the recipient limb was preferred ($p = 0.019$) because it causes less inconvenience while walking. In the lower extremity reconstruction, flap elevation from the same side of the recipient limb ($p = 0.002$) was preferred. The debulking procedure performed on the upper extremities at 4 weeks after reconstruction led to better functional results and enhanced patient satisfaction ($p = 0.022$). In the case of lower extremities, enhanced satisfaction was noted in patients who underwent the procedure at 6 months after reconstruction ($p < 0.001$).

Conclusions: Elevation of the flap in reconstruction reduced inconvenience when performed on the same side of the recipient limb for lower extremities and on the opposite side for upper extremities. In addition, debulking resulted in better satisfaction when performed 4 weeks postoperatively in the upper extremities and 6 months postoperatively in the lower extremities.

Keywords: *Upper extremity and lower extremity, Debulking, Anterolateral thigh flap*

Among traumas to the upper extremities (UEs) and lower extremities (LEs), severe soft tissue defects exposing ligaments or bones require surgery at the earliest possible time to prevent an infection. If associated with fractures, injuries need to be treated with rigid fixation for bone union together with neuroorrhaphy to relieve functional and sensory disturbances of the injured nerves. For severe soft

tissue injuries, however, reconstruction using a free flap is often necessary even after such aggressive treatments are performed.

Since the operating microscope was introduced for the treatment of injuries in the extremities in the 1960s,¹⁾ reconstruction of the extremities has been performed using various types of free flaps including the latissimus dorsi free flap,²⁾ dorsalis pedis free flap,³⁾ scapular free flap,⁴⁾ lateral arm free flap,⁵⁾ and anterolateral thigh (ALT) free flap.⁶⁾

The ALT free flap, among others, is currently widely used. The ALT flap was first described by Song et al.⁷⁾ in 1984, and was developed for widespread clinical application by Koshima et al.⁸⁾ Then, in 2007, Wei et al.⁹⁾ proved

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the efficacy of the ALT flap in soft tissue reconstruction. In 2012, Lee et al.¹⁰⁾ reported good results in their treatment of Gustilo type IIIB open tibia fractures using the ALT flap. ALT flap reconstruction has a reported success rate of over 90%,^{11,12)} and its focus has been gradually shifting from simple soft tissue reconstruction to achieving good functional and aesthetic outcomes to increase patients' postoperative satisfaction.⁹⁾

While reconstruction of soft tissue defects is the common purpose, reconstructions of the UEs and LEs have different goals in terms of functional and aesthetic outcomes.¹¹⁾ With only a limited number of studies published to date, we undertook an analysis of differences between reconstructions of UEs and LEs with respect to the preoperative preparation of the ALT flap and the timing of

a debulking procedure.

METHODS

In this study, we enrolled 72 patients who underwent reconstruction procedures (n = 74) using the ALT free flap between October 2006 and August 2012 for UE and LE injuries associated with soft tissue defects that exposed ligaments or bones. The mean follow-up period was 38 months (range, 20 to 59 months). Reconstruction using the ALT flap was performed on 45 UEs (UE group) and on 29 LEs (LE group).

In the UE group, crush was the major cause of injury (35 cases), followed by amputation (5 cases), friction (2 cases), frostbite (1 case), burn (1 case), and multiple lacerations (1 case) (Table 1). The most common mechanism of injury to the LEs was crush (22 cases), followed by ischemic necrosis (6 cases) and burn (1 case) (Table 2).

Differences between the UE and LE reconstructions were analyzed based on the postoperative satisfaction of

Table 1. Causes of Injury in Upper Extremity Reconstruction Group

Variable	Elbow	Forearm	Hand	Finger	Total (%)
Crush	2	3	23	7	35 (77.78)
Amputation	-	2	3	-	5 (11.11)
Friction	-	-	2	-	2 (4.44)
Frostbite	-	-	-	1	1 (2.22)
Burn	-	1	-	-	1 (2.22)
Laceration	-	1	-	-	1 (2.22)
Total (%)	2 (4.44)	7 (15.56)	28 (62.22)	8 (17.78)	45 (100)

Table 2. Causes of Injury in Lower Extremity Reconstruction Group

Variable	Tibia	Ankle	Foot	Toe	Total (%)
Crush	1	7	12	2	22 (75.86)
Ischemic necrosis	3	3	-	-	6 (20.69)
Burn	1	-	-	-	1 (3.45)
Total (%)	5 (17.24)	10 (34.48)	12 (41.38)	2 (6.90)	29 (100)

Table 3. Assessment of Inconvenience during Walking at One Month after Reconstruction

Score	Upper extremity group			Lower extremity group		
	SR (n = 10)	OR (n = 35)	p-value	SR (n = 20)	OR (n = 9)	p-value
Inconvenience level						
Can not move from bed (0)	0	0		0	0	
Use wheelchair with assistance (1)	1	0		0	5	
Use wheelchair without assistance (2)	6	4		3	4	
Can walk on crutches without assistance (3)	1	21		12	0	
Can walk with donor site pain (4)	2	7		4	0	
Can walk without donor site pain (5)	0	3		1	0	
Median (range)	2 (1–4)	3 (2–5)	0.008	3 (2–5)	1 (1–2)	< 0.001
IQR (Q3–Q1)	2–3	3–4		3–3.5	1–2	
Mean ± SD	2.40 ± 0.97	3.26 ± 0.78		3.15 ± 0.75	1.44 ± 0.53	

SR: flap elevation on the same side of the recipient limb, OR: flap elevation on the opposite side of the recipient limb, IQR: interquartile range, SD: standard deviation.

the patients with lower limb weakness according to the site selected for flap elevation and the timing of the debulking procedure.

The choice of donor site was analyzed from 2 perspectives at 1 year after reconstruction: (1) inconvenience during walking for 1 month after reconstruction assessed based on 6 objective criteria (Table 3) and (2) satisfaction of patients with the choice of the donor site that was divided into 5 categories for statistical analysis (Table 4). The timing of the debulking procedure and its results were also analyzed. The debulking procedure performed at 4 weeks after reconstruction when the flap began to stabilize was compared with that performed at 6 months after reconstruction when the flap was considered fully stabilized. The results were analyzed in terms of objective criteria

such as respective incidences of complications and subjective criteria such as satisfaction of patients with the timing of the procedure. The complications developed were contact ulcer, infection, hematoma, and itching (Table 5). Satisfaction of patients with the timing of the debulking procedure was categorized using 5 criteria for statistical analysis (Table 6). In addition, we compared the efficacy of the 2-team approach.

For statistical analyses, Wilcoxon rank sum test was used to evaluate significant differences between the donor site on the same side of the injured extremity and the donor site on the opposite side of the injured extremity in terms of postoperative inconvenience caused during walking and patient satisfaction with the site from which the flap was elevated. To assess significant differences in

Table 4. Patient's Satisfaction with Choice of Donor Site

Score	Upper extremity group			Lower extremity group		
	SR (n = 10)	OR (n = 35)	p-value	SR (n = 20)	OR (n = 9)	p-value
Satisfaction level						
Excellent (5)	0	1		0	0	
Good (4)	1	8		7	0	
Satisfactory (3)	4	23		12	4	
Fair (2)	4	1		1	5	
Poor (1)	1	2		0	0	
Median (range)	2.5 (1–4)	3 (1–5)	0.019	3 (2–4)	2 (2–3)	0.002
IQR	2–3	3–4		3–4	2–3	
Mean ± SD	2.50 ± 0.85	3.14 ± 0.77		3.30 ± 0.57	2.44 ± 0.53	

SR: flap elevation on the same side of the recipient limb, OR: flap elevation on the opposite side of the recipient limb, IQR: interquartile range, SD: standard deviation.

Table 5. Comparison of Complications

Variable	Upper extremity group			Lower extremity group		
	4 Weeks (n = 30)	6 Months (n = 15)	p-value	4 Weeks (n = 10)	6 Months (n = 19)	p-value
Type of complication						
Contact ulcer	0	0		2	0	
Infection	2	1		2	1	
Hematoma	1	0		1	0	
Itching	2	1		0	0	
No (%)	25 (83.3)	13 (86.7)	1.000	5 (50.0)	17 (94.4)	0.013
Yes (%)	5 (16.7)	2 (13.3)		5 (50.0)	1 (5.6)	

Table 6. Patient's Satisfaction According to the Timing of the Debulking Procedure

Score	Upper extremity group			Lower extremity group		
	4 Week (n = 30)	6 Month (n = 15)	p-value	4 Week (n = 10)	6 Month (n = 19)	p-value
Satisfaction level						
Excellent (5)	0	0		0	1	
Good (4)	11	1		0	7	
Satisfactory (3)	16	10		4	11	
Fair (2)	3	4		6	0	
Poor (1)	0	0		0	0	
Median (range)	3 (2–4)	3 (2–4)	0.022	2 (2–3)	3 (3–5)	<0.001
IQR	3–4	2–3		2–3	3–4	
Mean ± SD	3.27 ± 0.64	2.80 ± 0.56		2.40 ± 0.52	3.47 ± 0.61	

IQR: interquartile range, SD: standard deviation.

the postoperative satisfaction of patients with the timing of the debulking procedure, we performed the Wilcoxon rank sum test at 4 weeks and at 6 months after reconstruction. Fisher exact test was used to compare the incidence of complications according to the timing of the procedure in each extremity.

RESULTS

The mean size of the flap used for reconstruction was 90 cm² (range, 60 to 168 cm²). The mean length of the pedicle used for vessel anastomosis in the recipient site was 9 cm (range, 6 to 15 cm). In 69 cases, end-to-end anastomosis was performed. In 5 cases, T-anastomosis was performed. Among 74 cases, 68 (92%) survived and 6 required revision surgery. Of the 45 cases in the UE group, 43 (96%) survived, 1 developed partial necrosis and 1 developed total necrosis. Of the 29 cases in the LE group, 25 (86%) survived, 1 developed partial necrosis, and 3 developed total necrosis. The cause of necrosis was artery circulation insufficiency in 1 case and vein congestion in 3 cases. In the 2 cases of partial necrosis and 1 case of total necrosis, full-thickness skin graft was performed. For 3 cases of necrosis, distance local flaps were applied.

Among the 45 cases in the UE group, the thigh from which the flap was elevated was on the same side of the recipient limb in 10 cases and on the opposite side of the recipient limb in 35 cases. In the 29 cases in the LE group, the donor site was on the same side in 20 cases and on the opposite side in 9 cases. In the UE group, statistical analysis of inconvenience during walking for 1 month

after reconstruction revealed that when the donor site was on the same side, using a wheelchair without assistance was the most common solution (6 cases), whereas the use of a crutch on the opposite side of the upper limb was the solution when the donor site was on the opposite side of the recipient limb (21 cases). In the LE group, the use of a crutch on the opposite side of the recipient limb was the most common solution (12 cases) when the donor site was on the same side, whereas a wheelchair with assistance was the most common solution (5 cases) when the donor site was on the opposite side. In the UE group, when the flap was elevated from the opposite side of the affected extremity, patients experienced statistically significantly less inconvenience ($p = 0.008$), whereas in the LE group, patients found flap elevation from the same side of the affected extremity less inconvenient ($p < 0.001$) (Table 3).

In the survey of patient satisfaction with the choice of the donor site, 32 cases in the UE group had a score of ≥ 3 (satisfactory) when the donor site was on the opposite side of the recipient extremity. In the LE group, 19 cases had a score of ≥ 3 when the donor site was on the same side of the recipient extremity. In the UE group, patients were more satisfied when the flap was elevated from the opposite side ($p = 0.019$), whereas the LE group found the donor site on the same side of the affected extremity more satisfactory ($p = 0.002$) (Table 4).

The complications, which included contact ulcer, infection, hematoma, and itching, developed in 7 out of 45 cases in the UE group and in 6 out of 29 cases in the LE group (Table 5).

Among the 45 cases in the UE group, 30 underwent

Table 7. Comparison of Operative Time

Variable	Upper extremity group			Lower extremity group		
	One (n = 10)	Two (n = 35)	p-value	One (n = 20)	Two (n = 9)	p-value
Operative time (min)	321.2 ± 102.5	265.5 ± 82.5	0.035	387.2 ± 115.5	310.5 ± 112.5	0.028

One: 1-team approach, Two: 2-team approach.

debulking at 4 weeks and 15 at 6 months. Among the 29 cases in the LE group, 10 underwent the procedure at 4 weeks and 19 at 6 months. Complications were observed in 10 patients who underwent debulking at 4 weeks and 3 patients who underwent debulking at 6 months. The timing of debulking was irrelevant to the incidence of complications in the UE group ($p = 1.000$). In the LE group, the incidence was lower in the patients who underwent debulking at 6 months ($p = 0.013$).

In the UE group, 27 cases showed a satisfactory score of ≥ 3 when debulking was performed at 4 weeks. In the LE group, 19 cases were satisfied with debulking performed at 6 months. Statistical analysis of patient satisfaction with the timing of debulking showed that the UE group found debulking at 4 weeks satisfactory ($p = 0.022$), whereas the LE group expressed satisfaction with the procedure performed at 6 months ($p < 0.001$) (Table 6).

The 2-team approach was used only when the donor site was on the opposite side of the recipient extremity in both groups: 35 cases in the UE group and 9 cases in the LE group.

The 2-team surgical approach took significantly less time than the 1-team approach in the UE ($p = 0.035$) and LE ($p = 0.028$) groups (Table 7).

Functional results in the UE group with respect to the extent of injury were not statistically analyzed. However, when flap reconstruction was performed on important fingers or joints, satisfactory results were obtained by thinning the flap, which otherwise could hamper joint exercises, at 4 weeks after reconstruction when revascularization of the flap started. In the LE group, the incidence of complications was lower when debulking was performed at 6 months when the flap was stabilized.

DISCUSSION

Among the traumas to the UEs and the LEs, severe soft tissue defects exposing ligaments or bones require reconstruction to prevent an infection. Reconstruction methods largely include a skin graft, a local pedicle flap, a distant pedicle flap, and a free flap.¹³⁾

The primary purpose of reconstruction using the free flap is insulating the exposed tissue from the outside, but approaches to the UEs and the LEs are different in terms of functional and aesthetic aspects. The UE is the most exposed area after the face. Since it is an aesthetically important area, functional recovery for activities of daily living as well as aesthetic recovery should be the focus of treatment. The LEs, on the other hand, are largely hidden. Therefore, compared with the UEs, the basic functions of the LEs, such as the ability to wear shoes and walk without pain, are more important than aesthetic recovery.^{14,15)}

One of the complications related to the donor site in ALT flap reconstruction is lower limb weakness,¹⁶⁾ and other factors affecting postoperative ambulation are the size of the flap, extent of the associated injury, and associated diseases of the patient. However, selection of the donor site has different implications in the reconstruction of the UEs and LEs.

According to previous studies, in the reconstruction of the LEs, the donor site on the same side of the recipient extremity is advantageous because intraoperative positional change is not necessary.¹⁷⁾ However, in cases of femoral fractures, pelvic fractures, or soft tissue defects, the opposite side that have no vascular injuries is optimal for flap elevation.¹²⁾ These results are consistent with those of our study where satisfaction of patients with the choice of the donor site was significantly higher when the donor site was ipsilateral to the recipient extremity in the LE group and contralateral to the recipient extremity in the UE group.

Debulking procedures for aesthetic purposes are generally recommended at 6 months after reconstruction when the flap is fully vascularized, tissue edema is resolved, and the flap is stabilized with fat atrophy to some degree.^{18,19)} However, a study reported that patients with mental trauma showed better results when the procedure was performed 3 months after reconstruction because their aesthetic satisfaction with debulking improved confidence and encouraged proactive participation in rehabilitation.²⁰⁾ The present study statistically compared the results of debulking performed at 4 weeks and 6 months

after reconstruction. In the UE group, the incidence of complications was irrelevant to the timing of debulking and patients were more satisfied with debulking performed at 4 weeks after reconstruction. Therefore, it was considered advantageous for the UE group to undergo debulking at 4 weeks after reconstruction. The procedure thinned the flap particularly around joints and fingers, easing motor disturbances functionally and increasing aesthetical satisfaction. In the LE group, the incidence of complications was significantly lower and satisfaction of the patients was higher when debulking was performed at 6 months after reconstruction. The priority of the LE group is to be able to wear shoes and walk without complications. Thus, it is important to maintain the thickness of the flap to the extent at which wearing a shoe is possible once debulking is performed, preferably after 6 months from reconstruction.

Our study showed that in patients with soft tissue injuries exposing ligaments or bones, elevation of the flap from the opposite side of the recipient extremity and debulking at 4 weeks were associated with better outcomes and satisfaction in the reconstruction of the UEs, whereas elevation of the flap from the same side of the recipient extremity and debulking at 6 months were associated with better outcomes and satisfaction in the reconstruction of the UEs.

Unlike the UE group, deep vein thrombosis, chronic edema, and ischemic skin necrosis caused by arteriosclerosis or diabetes are often seen in the LE group.²¹⁻²³⁾ The flap in the LE with unstable blood circulation often leads to failure due to insufficient vascularization in the recipient site at the time of vessel anastomosis.²⁴⁾ In this study, the success rate for UE reconstructive surgery was 96%, but it was 86% for LE reconstructive surgery. Of the 4 cases in the LE group where the flap procedure failed, 3 patients had deep vein thrombosis and 1 had arteriosclerosis.

In general, the factors that most determine the operative time are the experience of the surgeons. However, there are two additional factors when it comes to ALT flap reconstruction. The first factor is anatomical structure.

Another factor is the simultaneous operation by 2 teams, which could reduce the operative time by half an hour to one and a half hour.¹³⁾ In our series, the choice of the donor site impacted the operative time. In the UE group, when the flap was elevated from the side opposite of the recipient site, the operative time was shortened due to the 2-team approach. In the LE group, on the other hand, patients experienced less inconvenience in walking when the donor site was on the same side of the recipient site, whereas the operative time was shortened when the donor site was on the opposite side. Therefore, further studies are necessary to decide whether patient satisfaction or reduced operative time is more important. Some limitations in this study should be acknowledged. First, the study was conducted retrospectively without considering the size of donor site and degree of injury in the recipient site and controlling for selection bias, which might have decreased patient satisfaction after surgery. Second, the lack of statistical analysis on intergroup differences in demographic characteristics could compromise the reliability of the findings.

In the UEs, postoperative rehabilitation was improved when the flap was elevated from the side opposite to the reconstruction site. In addition, the 2-team approach, which reduced the operative time, was possible. In the LEs, elevating the flap from the same side of the reconstruction site produced better results in postoperative rehabilitation. To obtain good functional results, debulking is recommended at the earliest possible time after reconstruction in the UEs and once the flap is fully stabilized for convenient walking in the LEs.

Understanding such differences between the UE and the LE when performing reconstruction using the ALT flap will help surgeons achieve better results.

CONFLICT OF INTEREST

No potential conflict of interest relevant to this article was reported.

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