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Reconstructive surgery for foot and ankle defects in pediatric patients: Comparison between anterolateral thigh perforator flaps and deep inferior epigastric perforator flaps

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ABSTRACT

Backgrounds: Due to the delicate tissue, small blood vessels and incomplete development of interarticular ligaments, skin and soft-tissue defects of the foot and ankle in pediatric patients remain a challenge for orthopedic and plastic surgeons. Anterolateral thigh perforator (ALTP) flap and deep inferior epigastric perforator (DIEP) flap are the most commonly used flaps for the repair of lower-extremity soft-tissue defects. The literature contains a shortage of evidence involving the differences between ALTP and DIEP flaps in the reconstruction of young patients with complex foot and ankle defects. This study was designed to determine which type of flap is better for foot and ankle repair in pediatric patients.
Methods: From January 2004 to January 2018, 79 children younger than 14 years treated with DIEP flap (41 cases) or ALTP flap (38 cases) for composite defects of the feet and ankles were retrospectively investigated. The two groups were homogeneous in terms of age, the location of the defect, etiology, and flap area. Complications, scarring, cosmetic appearance, flap sensory recovery, and functional outcome were analyzed, and statistical analysis was performed.
Results: The ALTP group had shorter operation time (155.0 ± 12.0 min vs 212.2 ± 23.9 min), flap harvested time (39.6 ± 5.1 min vs 57.2 ± 10.4 min), and operative blood loss (143.4 ± 23.7 ml vs 170.7 ± 44.7 ml) than the DIEP group ($P < 0.05$). In short-term follow-up, ALTP group showed a lower flap necrosis rate (5.3% vs 24.4%) and vascular insufficiency rate (2.6% vs 19.5%) than DIEP group ($P < 0.05$). In long-term follow-up, ALTP group showed a lower late complication rate and better cosmetic, functional, scar outcomes than DIEP group ($P < 0.05$).
Conclusions: The study showed that an ALTP flap may brings better results than a DIEP flap in terms of short- and long-term complications, scarring, and morpho-functional outcomes for pediatric patients undergoing reconstruction of foot and ankle defects.

Introduction

Reconstruction of foot and ankle defects in pediatric patients remains a great challenge for orthopedic and plastic surgeons [1–5]. A child victim who has suffered from high-energy damage such as a traffic accident is usually afflicted with complex skin tissue defects with exposure or loss of tendon and bone at the feet and ankles. Due to the small caliber of blood vessels, thin walls, and difficulties of nursing after the operation, the development of pediatric perforator flap transplantation is relatively slow [6–8]. At present, DIEP and ALTP flaps are the most commonly used flaps for the repair of composite soft-tissue defects in lower extremities [1,9–15]. In order to ensure aesthetic appearance and function of the limbs, free perforator flap reconstruction of posttraumatic defects in pediatric patients requires more elaborate design and skillful microsurgical technique. However, there has been no evidence regarding the difference between ALTP and DIEP flaps in the reconstruction of the pediatric foot and ankle defects. In this comparative study, we evaluated the foot and ankle reconstruction in pediatric patients through an analysis comparing DIEP and ALTP flaps, emphasizing the surgical techniques, short-term and long-term complications, functional outcomes, and scarring.

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Patients and methods

Patients

Seventy-nine pediatric patients with soft-tissue defects of the feet and ankles who underwent debridement and elective free perforator flap reconstruction from January 2004 to January 2018 were retrospectively reviewed. Among these patients, 41 were reconstructed using free DIEP from 2004 to 2013, and 38 were reconstructed using free ALTP from 2014 to 2018. This study was approved by the Ethics Committee of Xiangya Hospital, Central South University. Parents or guardians of patients signed an informed consent form. The two groups were similar in terms of age, reconstructed site, and etiology. Seventy-nine cases were caused by traumatic injuries; the other 8 cases were caused by scar contracture after trauma or chronic ulcer nonunion. All the operations were completed by a single surgeon and his team using the same surgical technique.

The inclusion criteria included the following: (1) The patients were under 14 years of age and had foot soft-tissue defects; (2) The parents or guardians of the patients agreed to have the children receive one-stage reconstruction surgery with ALTP or DIEP flaps on the recommendation of the primary treating surgeon. (3) When more than one flap was used to close the defect, these flaps were not included in this study.

Surgical technique

Initial debridement was conducted before the patients were referred to our department for reconstruction. Preoperatively, we detected and marked the perforators with the help of a handheld Doppler. In the ALTP group, 38 patients were reconstructed using a free ALTP flap (Fig. 1), which was carried out by the descending branch of the lateral circumflex femoral artery and cutaneous branch femoral nerve. In the DIEP group, 41 patients had reconstructions using a free DIEP flap (Fig. 2), which was supplied by the inferior epigastric artery. All DIEP and ALTP flaps were harvested through the “reverse tetrahedral elevation technique” [1,12]. The donor site was closed primarily with cosmetic suture.

Evaluation of outcomes

The observation time points of early complications from postoperative to discharge (mean 15 days) included the incidence of flap necrosis, vascular insufficiency, infection and hematoma in the reconstructed site, as well as infection and hematoma in the donor site. The follow-up period of 1 month, 3 months, 6 months and 12 months was used as the observation time points of late complications, including the incidence of flap bulky (e.g., shoe-wearing restrictions) [29],

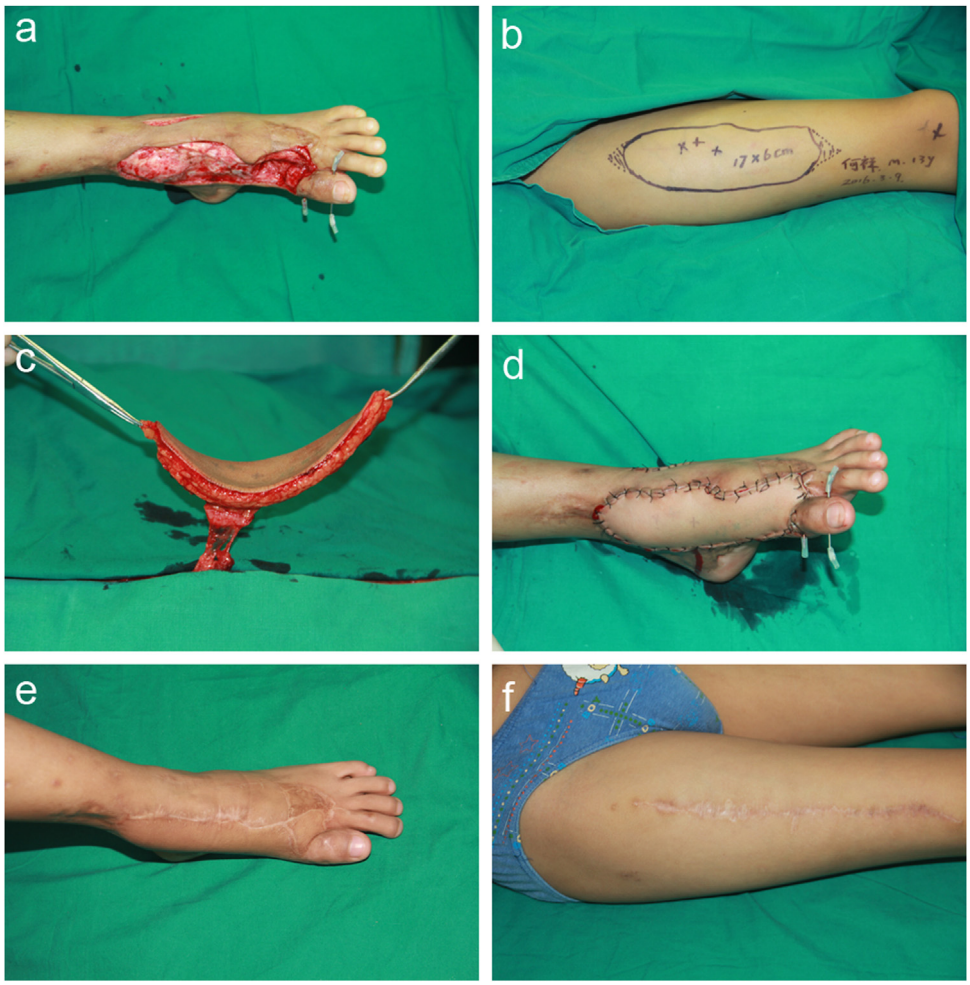

Fig. 1. (a) A 13-year-old boy with soft-tissue defects on the dorsum of foot; (b) An ALTP flap with 17 × 8 cm was designed. (c) The ALTP flap was harvested; (d) The ALTP flap was transferred to reconstruct defect; (e, f) Postoperative view of the recipient site and donor site at 12 months.

Fig. 2. (a) A 3-year-old boy with soft-tissue defects on the right foot and ankle; (b) The poly-DIEP flaps with 16 × 8 cm and 9 × 5 cm were designed; (c) The poly-DIEP flaps were harvested (d) The poly-DIEP flaps were transferred to reconstruct defect; (e,f) Postoperative appearance of the recipient site and donor site at 12 months; (g) The bulky flap was underwent the microdissected thin perforator flap technique; (h) Postoperative view of the recipient site at 10 months after microdissected thin surgery.

ulcer, and sensory recovery. Twelve months after surgery, the scars that had formed at both the reconstructed and donor sites were evaluated according to the Vancouver Scar Scale (VSS) in terms of their pigmentation, vascularity, pliability, and height. We subjectively evaluated the cosmetic appearance of the recipient sites and donor sites on a scale from 1 (close to normal) to 4 (unsatisfactory) [16–18]. The long-term cosmetic results were evaluated objectively by a blinded third-party observer. We also assessed functional outcomes by Kofoed ankle scores ranging from 0 to 100 with sub-scores for pain, function, and mobility (Kofoed score 85–100 as excellent, 75–85 as good, 70–74 as passing, and <70 as poor) [19.20]. Furthermore, we examined flap sensory recovery using Semmes-Weinstein monofilaments.

Statistical analysis

Quantitative data were expressed as the means ± standard deviation and compared using Student's t-test. Qualitative data were expressed as numbers or percentages and compared using the χ^2 test and Fisher's exact test. Statistical analysis was performed using SPSS 20.0 software (SPSS Inc., US). $P < 0.05$ was considered statistically significant.

Results

A total of 79 pediatric patients with soft-tissue defects of the feet and ankles participated in the retrospective study comparing free DIEP and ALTP flap reconstruction (Table 1). The DIEP

Table 1
Patients' characteristics.

Variable	DIEP Group ($N = 41$)	ALTP Group ($N = 38$)	P Value[#]
Age (year)	7.2 ± 2.5	8.0 ± 2.8	0.204
Sex			0.009
Male	38	26	
Female	3	12	
Etiology			0.713
Traumatic	36	35	
Others[*]	5	3	
Location of defect			0.903
A	8	9	
B	16	14	
A + B	17	15	
Flap area(cm^2)	110.3 ± 44.8	116.3 ± 61.8	0.630
Harvested time(min)	57.2 ± 10.4	39.6 ± 5.1	0.001
operation time(min)	212.2 ± 23.9	155.0 ± 12.0	0.001
Operative blood loss(ml)	170.7 ± 44.7	143.4 ± 23.7	0.001

DIEP, deep inferior epigastric artery perforator; ALTP, anterolateral thigh perforator. A, Foot; B, Ankle.
[*] Scar hyperplasia, chronic ulcer, internal fixation exposure.
[#] Two-sided Fisher's exact test.

group contained 38 males and 3 females with an average age of 7.2 ± 2.5 years, as well as 26 males and 12 females with an average age of 8.0 ± 2.8 years in the ALTP group. There were no significant differences in age, the location of the defect, flap area or etiology between the two groups. The ALTP group had shorter operation time (155.0 ± 12.0 min vs 212.2 ± 23.9 min), flap harvested time (39.6 ± 5.1 min vs 57.2 ± 10.4 min), and reduce operative blood loss (143.4 ± 23.7 ml vs 170.7 ± 44.7 ml) than the DIEP group ($P < 0.05$).

Short-term postoperative complications

At the short-term follow-up visit (Table 2), the flap complications, and donor-site morbidity was analyzed. Partial necrosis occurred in 9 cases in the DIEP group and in 2 cases in the ALTP group. Total necrosis occurred in one case of the DIEP group, and none occurred in the ALTP group. The results showed that the incidence of flap necrosis in ALTP group was significantly lower than that in DIEP group (5.3% vs 24.4%, $P < 0.05$). Among the factors of flap necrosis, the incidence of vascular insufficiency in ALTP group was significantly lower than that in DIEP group (2.6% vs 19.5%, $P < 0.05$), and there was no difference between the two groups of hematoma and infection. There was no significant difference between the two groups in terms of donor site morbidity ($P > 0.05$). Hematoma occurred in one case in the DIEP group and none in the ALTP group. Infection occurred in 3 cases in the DIEP group and in one case of the ALTP group.

Table 2
Evaluations at short-term follow-up.

Variable	DIEP Group ($N = 41$)	ALTP Group ($N = 38$)	P Value[#]
Flap complication			
Flap necrosis			0.026
Total flap necrosis	1	0	
Partial flap necrosis	9	2	
Factors of flap necrosis	8	1	0.030
Vascular insufficiency[a]			
Hematoma	2	1	–
Infection	3	1	–
Donor site morbidity			0.361
Hematoma	1	0	
Infection	3	1	

[a] Artery/Venous insufficiency.

If partial flap necrosis was noted during a dressing change, skin grafting or local flap transposition were performed. Meanwhile, one patient with total necrosis went on to undergo thoracodorsal artery perforator flap transplantation (Table 3).

Long-term postoperative complications

To evaluate the late complications of the reconstructed area, we used a numerical statement was in terms of the bulky flap, the defatting bulky flap, and the flap sensory recovery (Table 4). A bulky flap occurred in 23 cases in the DIEP group and in 4 cases in the ALTP group. The bulky flap defatting occurred in 15 cases of the DIEP group and in 2 cases of the ALTP group. In addition, 30 cases in the ALTP group recovered protective sensation, and none recovered protective sensation in the DIEP group. The results showed that the late complications in ALTP group were significantly lower than that in DIEP group ($P < 0.05$).

Postoperative patient satisfaction

In the overall cosmetic evaluations (Table 4), the subjective scoring showed that 27.5% of the DIEP patients rated their appearance as very good, 42.5% as good, 20% as satisfactory, and 10% as unsatisfactory. In the ALTP group, 47.4% of patients rated their appearance as very good, 44.7% as good, 7.9% as satisfactory, and none as unsatisfactory. The results showed that postoperative satisfaction of guardians of the patients in ALTP group was significantly better than that in DIEP group ($P < 0.05$). The blinded third-party observers also showed that the ALTP group was significantly better than the DIEP group ($P < 0.05$).

Postoperative functional evaluations

The function of the foot and ankle assessment showed that the ALTP group was significantly better than the DIEP group ($P < 0.05$). In the DIEP group, 37.5% took their functional outcomes as excellent, 35% as good, 17.5% as moderate, and 10% as poor. In the ALTP group, 65.8% took their functional outcomes as excellent, 26.3% as good, 7.9% as moderate, and none as poor.

Postoperative scar evaluations

In VSS (Table 5), the means ± standards (standard deviation) scores between DIEP and ALTP groups differed significantly. In the reconstructed site, significant differences were observed in pigmentation (DIEP, 1.5 ± 0.7 vs. ALTP, 0.6 ± 0.7), vascularity (DIEP, 1.3 ± 0.7 vs. ALTP, 1.0 ± 0.4), pliability (DIEP, 1.6 ± 0.6 vs. ALTP, 1.1 ± 0.3), height (DIEP, 1.6 ± 0.7 vs. ALTP, 1.1 ± 0.3), and total (DIEP, 5.9 ± 1.8 vs. ALTP, 3.8 ± 1.3). Scar formation at the reconstructed site showed that ALTP group was significantly lower than DIEP group ($P < 0.05$). The scar formation at the donor site was consistent with that at the reconstructed site in the two groups ($P < 0.05$).

Table 3
Complications in free perforator flaps transplantation.

	DIEP Group	ALTP Group
Partial necrosis	9	2
Dressing change	3	1
skin graft	5	1
Local flap transposition	1	0
Total necrosis[a]	1	0

[a] Thoracodorsal artery perforator flap was redesigned.

Table 4
Evaluations at long-term follow-up.

Variable	DIEP Group ($N = 40$)	ALTP Group ($N = 38$)	P Value[#]
Late complication			
Bulky Flap	23	4	0.001
Defatting bulky flap	15	2	0.001
Flap of sensory recovery	0	30	0.001
Ulcer	7	0	0.012
Cosmetic evaluation			
Subjectively [a]			0.048
Very good	11	18	
Good	17	17	
Satisfactory	8	3	
Unsatisfactory	4	0	
Objectively [b]			0.029
Very good	12	22	
Good	18	14	
Satisfactory	8	2	
Unsatisfactory	2	0	
Functional evaluation			0.033[c]
excellent	15	25	
good	14	10	
moderate	7	3	
poor	4	0	

[a] Guardians of the patients.
[b] Blinded third-party observer.
[c] Excellent and good rate.

Table 5
Scar evaluation according to the Vancouver scale.

Variable	DIEP Group ($N = 40$)	ALTP Group ($N = 38$)	P Value[#]
Reconstructed site			
Pigmentation	1.5 ± 0.7	0.6 ± 0.7	0.001
Vascularity	1.3 ± 0.7	1.0 ± 0.4	0.011
Pliability	1.6 ± 0.6	1.1 ± 0.3	0.001
Height	1.6 ± 0.7	1.1 ± 0.3	0.001
Total	5.9 ± 1.8	3.8 ± 1.3	0.001
Donor site			
Pigmentation	1.1 ± 0.7	0.5 ± 0.6	0.001
Vascularity	1.4 ± 0.8	0.8 ± 0.5	0.002
Pliability	1.7 ± 0.7	1.1 ± 0.3	0.001
Height	1.7 ± 0.7	1.1 ± 0.3	0.001
Total	5.8 ± 2.3	3.6 ± 1.5	0.001

Coexisting foot and ankle outcomes

According to Table 6 of the coexisting foot and ankle group, there was no significant difference in the flap area between the two groups ($P > 0.05$), and the flap area was significantly larger than that of the single foot or ankle group ($P < 0.05$). The time of flap acquisition, operation time, intraoperative blood loss, partial necrosis rate of the skin flap and incidence of flap bulking were compared between the two groups, and the results were consistent with the statistical analysis results in Table 1 ($P < 0.05$).

Table 6
The differences between both groups regarding coexistent ankle and foot.

Variable	DIEP Group ($N = 17$)	ALTP Group ($N = 15$)	P Value[#]
Flap area(cm^2)	154.4 ± 31.2	179.7 ± 44.0	0.068
Harvested time(min)	64.4 ± 8.8	38.5 ± 4.4	0.001
operation time(min)	227.7 ± 18.6	150.7 ± 12.2	0.001
Operative blood loss(ml)	182.4 ± 49.8	146.7 ± 29.7	0.019
Partial necrosis	7	1	0.041
Bulky Flap	10	3	0.036

Discussion

At present, reconstructing complex soft-tissue defects of the foot and ankle in pediatric patients pose a major challenge for surgeons. Microsurgical techniques have been advocated as an ideal method to repair extensive defects in terms of the best function and appearance obtained but greatly lessening the damage. Free perforator flaps, particularly the DIEP and the ALTP, have become the mainstays of foot and ankle reconstruction for larger soft-tissue defects in children [1,2,8,21].

The DIEP flap has been a valuable tool in the field of plastic surgery since its first description by Koshima and Soeda in 1989, but mainly in breast reconstruction [22,23]. Ju-yu Tang et al. reported their clinical experience of 22 cases of DIEP flaps for repairing the skin and soft-tissue defects of pediatric extremities and obtained satisfactory results.[1] It has the following advantages: (1) Reliable blood supply can be cut off a large area with strong anti-infective ability; (2) The flap is thin and elastic, and the shape and function recovery for repairing foot and ankle defects (especially dorsum pedis or back of the heel) is good; (3) DIEP does not carry the anterior rectus sheath and rectus abdominis muscle and has no obvious effect on abdominal wall function. Some of the disadvantages of free DIEP are inevitable. The major disadvantage of DIEP is fat hypertrophy. When young patients grow up or become overweight, the flap at the reconstructed site may become bulky. Other disadvantages are the consequence of scar left on the abdominal wall and lack of a specific sensory innervation, which may bring problem at girl's pregnancy in the future and is prone to wear, scalds, and non-sensory ulcers at the ankle and foot, resulting in bad functional outcomes [1,8,13,14].

The ALTP flap, based on the descending branch of the lateral circumflex femoral artery in the thigh, has emerged as one of the most commonly used flaps since first described by Song et al. in 1984 [24]. Rui et al. reported that large soft-tissue defects at the foot and ankle were repaired by anterolateral thigh flap and iliotibial band, from satisfactory results were obtained [2]. The advantages of this approach include versatility in design, adequate tissue stock, superior texture, and minimal donor-site morbidity. In addition, this flap cutting fascia latae is a good choice to reconstruct the special structure of the heel. If carrying the lateral femoral cutaneous nerve, the ALTP can also recover the local protective sensation at the foot and ankle. Disadvantages of ALTP include the following: (1) Due to the nonconstant position of the perforator flap, Doppler ultrasound flow detector or color Doppler is always used to determine the accurate position to reduce the surgical risk. (2) Due to the thick hair of some male patients, the appearance of the recipient site (such as hand, foot, and tongue) is always unsightly, and postoperative treatment of hair removal is often needed [2,8,12,25,26]. A bulky flap is common after flap transplantation. Cho JY et al reported that as the child grows, the perforator flap will continue to expand, but its growth will not affect the normal development and function of the foot. Related research results show that in addition to the expansion of the flap during growth, there is also the possibility of the bulky flap [27]. Therefore, a secondary debulking is often required to improve the shape and function of the recipient site. Although there are many treatment methods for a bloated flap, there are still many defects, such as many times of operation, the large area of repair, necrosis of the edge of flap and poor texture of skin after the operation [28,29], The results of this study showed that the incidence of bulky flaps and secondary debulking was significantly lower in the ALTP group than in the DIEP group in pediatric patients.

In pediatric patients with foot and ankle defects, ALTP with fascia lata and lateral femoral cutaneous nerves can provide good stability in repairing the plantar part of the heel and pelma, reconstructing protective sensation simultaneously [30–32]. The

DIEP flaps have the advantage of being thin and elastic, and they are a good choice to repair the dorsum pedis or back of the heel, which requires ductility to adjust the foot function. However, DIEP flaps have the disadvantages of oversize, poor stability, and lack of sensory innervation in the repair of lower-extremity defects. As a result, burns, frostbite, abrasion, secondary ulcers and affecting shoe wearing may occur after surgery, which affects the patient's weight loading and walking [1,13]. In this study, The recovery rate of protective sensation and low incidence of ulcer in ALTP group was significantly better than that in DIEP group. The appearance results and functional outcomes of the ALTP group were higher than those of the DIEP group. In addition, the study found that the incidence of early flap complications such as flap necrosis and vascular insufficiency in the DIEP group was higher than that of ALTP. In general, better results were shown in pediatric patients with foot and ankle defects reconstructed using ALTP flaps compared with DIEP flaps, which should be considered for future microsurgical designing and harvesting.

The most serious limitation of this study is that this study employed historical comparison. All of the operation were performed by single surgeon, meaning that the superiority of ALTP, shorter operative time, smaller bleeding volume, and lower complication rate, may be caused by just learning effect or improvement of other techniques during this study period. Also, this study has multiplicity issues with this limited case number. To establish the optimal treatment protocol for pediatric patients undergoing complex injury of feet and ankles, a large-scale, hospital-based case–control study with long-term follow-up is required in the future.

Conclusion

Free ALTP and DIEP flaps are important options for pediatric patients in foot and ankle defects reconstruction. Comparing the complications, cosmetic appearance, functional outcome, and scar evaluation, a higher rate of both short- and long-term complications, scarring, and unsatisfactory morpho-functional outcomes were observed in the DIEP group. Therefore, it appears that the ALTP flap may more suitable than the DIEP flap. In addition, the choice between the two types of free perforator flaps is likely to be decided by the reliability of their individual surgical procedure and local tissue availability.

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References

[1] Tang J, Fang T, Song D, Liang J, Yu F, Wang C. Free deep inferior epigastric artery perforator flap for reconstruction of soft-tissue defects in extremities of children. Microsurgery 2013;33(8):612–9.
[2] Hu R, Ren YJ, Yan L, Xiao ZH, Ding F, Li F, et al. A free anterolateral thigh flap and iliotibial band for reconstruction of soft tissue defects at children's feet and ankles. Injury 2015;46(10):2019–23.
[3] Grandjean A, Romana C, Fitoussi F. Distally based sural flap for ankle and foot coverage in children. Orthop Traumatol Surg Res 2016;102(1):111–6.
[4] Zheng H, Liu J, Dai X, Schilling AF. The distally based sural flap for the reconstruction of ankle and foot defects in pediatric patients. Ann Plast Surg 2016;77(1):97–101.
[5] Lin CH, Mardini S, Wei FC, Lin YT, Chen CT. Free flap reconstruction of foot and ankle defects in pediatric patients: long-term outcome in 91 cases. Plast Reconstr Surg 2006;117(7):2478–87.
[6] Aboelatta YA, Aly HM. Free tissue transfer and replantation in pediatric patients: technical feasibility and outcome in a series of 28 patients. J Hand Microsurg 2013;5(2):74–80.
[7] Tsai J, Liao HT, Wang PF, Chen CT, Lin CH. Increasing the success of reverse sural flap from proximal part of posterior calf for traumatic foot and ankle reconstruction: patient selection and surgical refinement. Microsurgery 2013;33(5):342–9.
[8] Zhu YL, Wang Y, He XQ, Zhu M, Li FB, Xu YQ. Foot and ankle reconstruction: an experience on the use of 14 different flaps in 226 cases. Microsurgery 2013;33(8):600–4.
[9] Van Landuyt K, Hamdi M, Blondeel P, Tonnard P, Verpaele A, Monstrey S. Free perforator flaps in children. Plast Reconstr Surg 2005;116(1):159–69.
[10] Song JW, Ben-Nakhi M, Hong JP. Reconstruction of lower extremity with perforator free flaps by free style approach in pediatric patients. J Reconstr Microsurg 2012;28(9):589–94.
[11] Acar MA, Güleç A, Aydin BK, Erkoçak ÖF, Yilmaz G, Şenaran H. Reconstruction of foot and ankle defects with a free anterolateral thigh flap in pediatric patients. J Reconstr Microsurg 2015;31(3):225–32.
[12] Qing L, Wu P, Liang J, Yu F, Wang C, Tang J. Use of flow-through anterolateral thigh perforator flaps in reconstruction of complex extremity defects. J Reconstr Microsurg 2015;31(8):571–8.
[13] Mahajan AL, Van Waes C, D'Arpa S, Van Landuyt K, Blondeel PN, Monstrey S, et al. Bipedicled DIEAP flaps for reconstruction of limb soft tissue defects in male patients. J Plast Reconstr Aesthet Surg 2016;69(7):920–7.
[14] Akdag O, Karamese M, Yildiran GU, Sutcu M, Tosun Z. Foot and ankle reconstruction with vertically designed deep inferior epigastric perforator flap. Microsurgery 2017;38(4):369–74.
[15] Gelidan AG. Salvage of planned ALT flap with rectus femoris free flap for pediatric lower extremity reconstruction: a demonstrative case report. Int J Surg Case Rep 2018;51:67–70 (undefined).
[16] Hamdi M, Larsen M, Craggs B, Vanmierlo B, Zeltzer A. Harvesting free abdominal perforator flaps in the presence of previous upper abdominal scars. J Plast Reconstr Aesthet Surg 2014;67(2):219–25.
[17] Cigna E, Rizzo MI, Greco A, De Virgilio A, Palmieri A, Maruccia M, et al. Retromolar trigone reconstructive surgery: prospective comparative analysis between free flaps. Ann Surg Oncol 2015;22(1):272–8.
[18] Thompson CM, Sood RF, Honari S, Carrougher GJ, Gibran NS. What score on the Vancouver Scar Scale constitutes a hypertrophic scar? Results from a survey of North American burn-care providers. Burns 2015;41(7):1442–8.
[19] Kofoed H, Sorensen TS. Ankle arthroplasty for rheumatoid arthritis and osteoarthritis: prospective long-term study of cemented replacements. J Bone Joint Surg Br 1998;80(2):328–32.
[20] van der Heide HJ, Schutte B, Louwerens JW, van den Hoogen FH, Malefijt MC. Total ankle prostheses in rheumatoid arthropathy: outcome in 52 patients followed for 1-9 years. Acta Orthop 2009;80(4):440–4.
[21] Lee SH, Suh JT, Ahn TY, Hong SM, Lee HY. Differences between the upper extremity and the lower extremity in reconstruction using an anterolateral thigh perforator flap. Clin Orthop Surg 2017;9(3):348–54.
[22] Koshima I, Soeda S. Inferior epigastric artery skin flaps without rectus abdominis muscle. Br J Plast Surg 1989;42(6):645–8.
[23] Lee BT, Agarwal JP, Ascherman JA, Caterson SA, Gray DD, Hollenbeck ST, et al. Evidence-based clinical practice guideline: autologous breast reconstruction with DIEP or pedicled TRAM abdominal flaps. Plast Reconstr Surg 2017;140(5):651e–64e.
[24] Song YG, Chen GZ, Song YL. The free thigh flap: a new free flap concept based on the septocutaneous artery. Br J Plast Surg 1984;37(2):149–59.
[25] Xie S, Deng X, Chen Y, Song D, Li K, Zhou X, et al. Reconstruction of foot and ankle defects with a superthin innervated anterolateral thigh perforator flap. J Plast Surg Hand Surg 2016;50(6):367–74.
[26] Seth AK, Iorio ML. Super-thin and suprafascial anterolateral thigh perforator flaps for extremity reconstruction. J Reconstr Microsurg 2017;33(7):466–73.
[27] Cho JY, Suh HS, Hong JP. Do skin perforator flaps accommodate foot growth in children after reconstruction? J Reconstr Microsurg 2016;32(9):650–6.
[28] Nelson JA, Fischer JP, Haddock NT, Mackay D, Wink JD, Newman AS, et al. Striving for normalcy after lower extremity reconstruction with free tissue: the role of secondary esthetic refinements. J Reconstr Microsurg 2016;32(2):101–8.
[29] Zhou ZB, Pan D, Wu PF, Yu F, Pang XY, Xiao YB, et al. Utilization of microdissected thin perforator flap technique in the treatment of bulky and deformed skin flaps. Ann Plast Surg 2018;80(6):634–8.
[30] Debelmas A, Camuzard O, Aguilar P, Qassemyar Q. Reliability of color doppler ultrasound imaging for the assessment of anterolateral thigh flap perforators: a prospective study of 30 perforators. Plast Reconstr Surg 2018;141(3):762–6.
[31] Noel CW, Vosler PS, Hong M, Orsini M, Sultanov F, Lu Z, et al. Motor and sensory morbidity associated with the anterolateral thigh perforator free flap. Laryngoscope 2017;128(5):1057–61.
[32] Maruccia M, Fallico N, Cigna E, Ciudad P, Nicoli F, Trignano E, et al. Suprafascial versus traditional harvesting technique for free antero lateral thigh flap: a case-control study to assess the best functional and aesthetic result in extremity reconstruction. Microsurgery 2017;37(8):851–7.