

# The Free Anterolateral Thigh (ALT) Flap for Microsurgical Reconstruction of Traumatic Defects in Pediatric Foot: A Systematic Review of International Literature

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## Abstract

**Objective:** Microsurgery has found early application in pediatric population despite the initial concerns on the technically challenging microanastomosis. Complex injuries of lower extremities in children have not received the same attention in the international literature, but some specific accidental foot injuries seem to have a particularly high frequency in that age group. The muscle flaps were initially the choice for the coverage of distal lower limb deficits; however, the donor site morbidity and the bulky appearance attracted attention to more delicate flaps, with the fasciocutaneous anterolateral thigh (ALT) flap becoming a basic reconstructive option. The present study considered all journal abstracts and articles on the use of free flaps in children's extremities in order to evaluate the use of the free ALT flap in pediatric patients. The literature search was performed with "PubMed" and "MEDLINE" databases according to PRISMA guidelines with the systematic review clustering eventually the results of 12 different studies. We investigated the use of 102 free ALT flaps for the reconstruction of traumatic foot defects in children with 95.1% flap survival rate and only 2 complete flap losses noted due to venous thrombosis; 6 flaps went for urgent re-exploration resulting in the unavoidable loss of one flap and the partial necrosis of 3 others. In the vast majority of cases the reconstruction was delayed and the total complication rate was 21.57%. It is reaffirmed that hypertrophic scarring tends to be more common in pediatric patients and split thickness skin graft should be avoided whenever primary closure without extensive tension is possible. More than a quarter (27.27%) of the children necessitated a secondary revision surgery, as the child's growth and the additional fat tissue make secondary debulking procedures really common. Special perioperative care, atraumatic dissection technique, and well established microsurgical experience are absolutely required when performing a free flap reconstruction in children. Nevertheless, the good functional outcome and the high survival rate of our review highlight the reliability of the free ALT flap for traumatic defects in pediatric foot.

**Keywords:** ALT flap; anterolateral thigh flap; pediatric foot; trauma; systematic review

## Introduction

Since its very first days, microsurgery has found application to pediatric population [1,2]. However, there has been reluctance in the widespread use of free tissue transfer in younger age groups, with the initial concerns on the technically challenging microanastomosis in children gradually phasing out and eventually large series on free flap reconstruction in pediatric patients being published [3,4]. Complex injuries of lower extremities in younger age are relatively rarer [5], basically due to the special protective measures in children's activities and car travel, and thus they may not receive the same attention with adults in the international literature. On the other hand, some specific accident mechanisms such as car tire run over [6,7] and lawn mower ride on [8] foot injuries have a particularly high frequency in the pediatric population because of the age related reduced risk perception and smaller body type. With the mitigation of the initial reservations and the regular use of free perforator flaps in children, the muscle and myocutaneous type flaps were the first choice for the optimal coverage of the distal lower limb deficits [9,10]. However, the donor site morbidity and the bulky appearance of the reconstructed area have attracted attention to more delicate flaps, with the fasciocutaneous anterolateral thigh (ALT) flap becoming a basic reconstructive option. Bibliographic references for the use of free septocutaneous perforator ALT flap in pediatric injuries are considered sporadic since the first description of the technique back in 1984 [11]. The present Systematic Review attempts to lead to a safe conclusion on the reliability of the ALT flap in traumatic foot injuries in children.

## Methods

### Purpose of review

The present study considered all journal abstracts and articles on the use of free flaps in children's extremities in order to evaluate the use of the free anterolateral thigh (ALT) flap in pediatric patients.

### Research question

Focusing on the referring flap survival rate and the related complications, this study is estimating if the technique is a safe and reliable reconstructive choice for traumatic defects in children's foot.

### Literature search

A preliminary search did not reveal the existence of a relevant systematic review concentrated on the use of ALT flap in pediatric foot

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Eligibility Criteria
English language
Retrospective reviews, systematic reviews and case reports
Defined age range
Population including children younger than 18 years old
Free flap reconstruction including the use of free ALT flap
Stated flap survival rate
Clear reference of defect's anatomic site
Foot included as a reconstructed area with ALT flap
Number and type of complications stated
Number and outcome of re-exploration procedures
Etiology of defect analysed
Trauma included as cause of defect

Table 1: Systematic Review inclusion criteria.

after trauma. The literature search was performed with “PubMed” and “MEDLINE” databases according to PRISMA guidelines.

### Search strategy

A primary search was carried out using keywords: “children”, “free flap” and “lower extremity” in “PubMed” and “ClinicalKey” (for full-text and “MEDLINE” journal articles) resulting in 429 and 556 citations respectively. Any duplicate publications or studies that did not match our research subject were excluded. Secondary screening located abstracts and articles meeting simultaneously three basic characteristics: study population with defined age range and patients under 18 years old, free flap reconstruction including free ALT flap, defect site including lower limb. In the final phase, 23 full-text articles have been assessed for eligibility with 12 studies reaching all the established criteria analysed in Table 1.

### Study quality and data analysis

The present systematic review clusters the results of 12 different studies on the use of free ALT flap with a total gathered population homogenous on the parameters of technique used (free ALT flap), age (pediatric patients younger than 18 years old), reconstructed defect anatomic site (feet), and etiology (trauma). A global statistical analysis on the flap survival, complications and re-exploration rate was possible and a further qualitative analysis on several perioperative and technical recorded features was also conducted.

### Limitations

An obvious limitation is that the patients included in the review have been operated in different institutions worldwide, by different surgeons and in different periods; however the expected bias is limited by the fact that all surgeons involved were experienced and the core principals of the technique used was identical. Moreover, some features (timing of reconstruction, recipient vessel used, number of veins anastomosed, post-operative coagulation) that potentially influence the survival or complication rate, are not systematically reported. Finally, the follow-up period is not similar and the concomitant injuries are not consistently reported in all the studies included.

### Results

The present Systematic Review is based on 12 studies that fulfil all the prerequisite inclusive criteria. The eligible selection consists of 11 Retrospective Reviews and 1 Case Report published from 2010 until 2017; their basic aspects are presented in Table 2.

A total number of 102 free ALT flaps used for the reconstruction of traumatic defects in children's feet have been collected with a follow-up

period ranging from 7 to 96 months. 75 male and 27 female pediatric patients with mean age just less than 10 years have been included in the review, with the youngest being a 2 and the oldest a 17 years old boy.

The flap survival rate is estimated as 95.1% with only 2 complete flap losses noted due to venous thrombosis. 6 out of the 102 free ALT flaps went for urgent re-exploration resulting in the unavoidable loss of one flap and the full salvation of two others after a venous re-anastomosis and the evacuation of an haematoma; 3 ended up with partial flap necrosis. The total complication rate was 21.57% with hypertrophic scar, infection needing intravenous antibiotic treatment, haematoma, wound dehiscence and limited skin necrosis comprising the list of minor complications occurring.

The most recent study is the Case Report published this July by Merter et al. [11-15] referring to a 2 years old boy with a car-tyre friction/avulsion injury to his left foot [16-22]. The defect was reconstructed successfully with an immediate ipsilateral ALT flap leaving the boy with no restrictions and a normal gait just 6 weeks post-operatively, eventually needing a revision with liposuction after 8 years.

The oldest review included is that of Demitras et al. [22] published on 2010 which is a retrospective analysis of a successful ALT flap reconstruction of car-tyre injuries to 5 pre-school children's feet. One flap of this series required re-exploration on the first post-operative day for evacuation of a haematoma and additionally wound infection and hypertrophic scarring presented in three other patients. During the follow-up, the outcome was evaluated as good with only minor gait abnormalities in two children.

The Retrospective Review of El-Gammal et al. [16] is the largest study included, analysing the delayed ALT flap reconstruction of 42 traumatic defects on the dorsum and ankle of pediatric feet. The flap survival rate was 92.86% with three of them undergoing a re-anastomosis after venous congestion resulting in one complete and two partial flap losses. Additionally, 5 hypertrophic scars were detected, but during the follow-up period and after debulking revision in 15 children, the final result was deemed satisfactory in almost all patients.

Another relatively large Retrospective Review that we included was the one of Hu et al. [14] which analysed the delayed ALT flap reconstruction of traumatic defects over the foot and ankle of 25 pediatric patients after high-energy accidents. In all the cases, iliotibial band with length from 3 to 16 cm have been also used to repair the coexisting tendon and ligament defects. All flaps survived with two of them presenting limited distal necrosis treated conservatively. 5 children underwent flap revision procedures after 6 months with 92% of the overall result rated from good to excellent.

Several other studies have not qualified for our systematic review even though they describe the use of free ALT flap for reconstruction in children. Indicative is the retrospective review of Song et al. [23] which presents the use of 18 free ALT flaps (mean flap size 162.8 cm, pedicle length 10 cm, artery diameter 0.8 mm) for reconstruction of pediatric lower extremity injuries, without nevertheless specifying the exact anatomic site and the etiology (15.47% traffic accident) of the defect. Worth notable is though the fact that in this series a 9 years old boy suffered from compartment syndrome at the donor site needing an urgent exploration at the second post-operative day. Another relevant Retrospective Review is that of Li et al. [24] describing the successful post-traumatic free ALT flap reconstruction in 11 children as a second stage procedure after a previous debridement and vacuum sealing drainage of the lower extremity wound. This study was excluded as the exact

n	Study	Type of study	F-U (months) Range (mean)	Gender (M/F)	Age (years) Range (mean)	ALT (n)	Flap Survival (%)	Complete Flap loss	Partial Flap Necrosis	Total complication rate (%)	Type of minor complications	Re-exploration (%)
1	Merter et al. [11] 2017	CR 2006	96	1/0	2	1	1/1 (100%)	0	0	0	NA	0
2	Lee et al. [12] 2016	RR 2012-15	7-15 (10)	1/0	11	1	1/1 (100%)	0	0	0	NA	0
3	Acar et al. [13] 2015	RR 2010-13	13-29 (20.7)	9/2	3-15 (8.9)	11	10/11 (90.9%)	0	1 (SSG)	3/11 (27.3%)	2 hypertrophic scars in donor site (massage)	1/11 Venous thrombosis (vein graft)
4	Hu et al. [14] 2015	RR 2008-13	6-24 (14.2)	16/9	4.5-14 (8.32)	25	25/25 (100%)	0	0	2/25 (8%)	2 minor distal necrosis (conservative management)	0
5	Marcondes et al. [15] 2015	RR 1997-2012	NR	4/1	4-12 (8)	5	4/5 (80%)	1 Venous thrombosis (MCgracillis flap)	0	1/5 (20%)	NA	0
6	El-Gammal et al. [16] 2012	RR 2005-10	42	32/10	2.5-13 (6.18)	42	39/42 (98.6%)	1 Venous thrombosis	2	8/42 (19%)	5 hypertrophic/keloid scars (conservative management)	3/42 Venous congestion (re-anastomosis)
7	Akcal et al. [17] 2013	RR 1997-2010	49	2/2	8-13 (11)	4	5/5 (100%)	0	0	1/5 (20%)	Wound dehiscence (conservative management)	0
8	Liu et al. [18] 2013	RR 2003-11	NR	0/1	17	1	1/1 (100%)	0	0	0	0	0
9	Napier et al. [19] 2012	RR 12 months	NR	2/0	4-5 (4.5)	2	2/2 (100%)	0	0	0	NA	0
10	Arslan et al. [20] 2012	RR 1998-2010	34	1/1	11-15 (13)	2	2/2 (100%)	0	0	1/2 (50%)	Cellulitis (IV antibiotics)	0
11	Gharb et al. [21] 2011	RR 1998-2009	36	3/0	6-17 (10.7)	3	3/3 (100%)	0	0	2/3 (66.67%)	Further necrosis of native skin (SSG)	1/3 Venous thrombosis (vein graft)
12	Demitras et al. [22] 2010	RR 2006-10	18-41 (27.4)	4/1	4-6 (4.8)	5	5/5 (100%)	0	0	4/5 (80%)	1 haematoma (evacuation) 1 infection (IV antibiotics) 2 hypertrophic scars (conservative management)	1/5 haematoma (evacuation)
Total			7-96	75/27	2-17 (9.65)	102	97/102 (95.1%)	2/102 (1.96%)	3/102 (2.94%)	22/102 (21.57%)		6/102 (5.88%)

(F-U=Follow-Up, M/F=Male/Female, RR=Retrospective Review, CR=Case Report, NR=Not Recorded, NA=Not Applicable, MC=Myocutaneous, IV=Intavenous)

**Table 2:** Free ALT flap for microsurgical reconstruction of traumatic defect in pediatric foot.

anatomic site, the complications and the revision procedures were not clearly stated in link with the ALT flap use. Finally, we must make a special mention of the Retrospective Review of Rajacic et al. [25] which is one of the earliest published studies (1994) depicting the free flap (mostly Latissimus Dorsi muscle flap) reconstruction of avulsion injuries in 40 children's feet; this review was excluded from the present study due to lack of clear connection of the survival and the complication rate with the 3 ALT flaps used.

In Table 3 we present a further analysis of important perioperative qualitative characteristics from the selected studies regarding the microsurgical reconstruction of the pediatric foot with free ALT flap. We can extract valuable information, even though the data is not consistently and homogeneously recorded in all those studies.

Regarding the timing of reconstruction, 83 ALT flaps were delayed from the time of injury (mostly as a secondary phase after initial debridement) with only 7 immediate reconstructions. The donor site was closed directly in 42 cases and SSG was used at least in 18 children's

thighs. The hospitalization was estimated in a mean period of 10 days according to the recorded data.

Flap revision procedures for debulking were conducted in 27 children, with the relative percentage being greater than one quarter (27.27%) of the initially operated pediatric patients. The final functional outcome was generally considered satisfactory with only some minor abnormalities noted.

In Table 4 we analyse elements related to the microsurgical technique used. In 26 pediatric patients extra fascia (fascia lata or iliotibial band) was used for an additional tendon repair at the injury. The flap size ranged from 54 to 252 cm<sup>2</sup>, with a mean of 119.53 cm<sup>2</sup>. The operative time is estimated at approximately 6 h and the relevant flap warm ischemia time more than one and a half hours. Most of the perforators' course was as expected musculocutaneous and in the largest series Dextran has been used for 5 days post-operatively as protocol coagulation. The anterior tibial has been the first choice as the recipient artery and also in several cases a second vein was also used.

n	Study	ALT (n)	Donor site closure	Timing of reconstruction	Hospitalization (days) mean (range)	Flap Revision	Long-term problems	Functional outcome
1	Merter et al. [9] 2017	1	DC	Immediate	7	2 sessions of debulking-liposuction (after 8 years)	0	After 4 weeks no restrictions, normal gait, running, shoe wearing
2	Lee et al. [10] 2016	1	NR	Delayed – 7 years	NR	0	0	Excellent comfort with shoes
3	Acar et al. [11] 2015	11	DC	10 Delayed (after debridement) 1 Immediate	NR	4/11 Flap thinning (after 8-10 months)	1 leg length discrepancy 1 heel ulcer 1 chafing on plantar surface 1 1st toe contracture	3 patients with mild restrictions in foot ROM
4	Hu et al. [12] 2015	25	<10cm DC >10cm SSG	Delayed >72 hours (after debridement +bone fixation)	15.1 (12-24)	5(3 × 2) Debulking (after 6 months)	0	Excellent/Good 23/25 (92%) (Maryland Foot Score)
5	Marcondes et al. [13] 2015	5	NR	NR	NR	0	NR	Walking without orthotics
6	El-Gammal et al. [14] 2012	42	25 DC 17 SSG	Delayed >72 hours (after debridement +bone fixation)	7.5	15/42 Debulking *thinning of 5 flaps prior to insertion	2 patients with difficulty in shoe wearing	90% with good walk/ climb/shoe ware
7	Akcal et al. [15] 2013	4	NR	NR	NR	0	NR	NR
8	Liu et al. [16] 2013	1	SSG	NR	NR	0	NR	Fatigue on stairs in one patient
9	Napier et al. [17] 2012	2	DC	NR	8.5 (7-10)	0	0	Excellent (Enneking score)
10	Arslan et al. [18] 2012	2	NR	Delayed – 22 days	NR	2/2 Debulking	0	Amputatory with orthotic footwear
11	Gharb et al. [19] 2011	3	DC	1 Immediate 2 Delayed (debridement of 1 previous SSG and 1 previous free flap)	NR	NA	0	NR
12	Demitras et al. [20] 2010	5	NR	4 Immediate 1 Delayed – 1 year	12	0 *thinning of flaps prior to insertion	1 1st toe contracture 1 4th toe contracture	Minor gait abnormalities in 2 patients
Total		102	42 DC 18 SSG 42 NR	7 Immediate 83 Delayed 12 NR	10 (7-24) 27 NR	27/99 (27.27%)		

(NR=Not Recorded; DC=Direct Closure; SSG=Split Thickness Skin Graft; NA=Not Applicable)

**Table 3:** Perioperative qualitative characteristics of microsurgical reconstruction with free ALT on children's traumatic foot defect.

## Discussion

### Microsurgery in children

The present review confirms the successful implementation of microsurgery in pediatric population. It is a fact though, that the application of the free perforator flaps in children was originally delayed in relation to adults due to reservations related to the small size of the vessels and the supposed increased vasospasticity [26]. Initially, Gilbert considered that 0.7 mm was the lowest size limit for microanastomosis [27] and in the same time a relatively low rate of free flap survival in children was reported [28,29]. However, those restrictions were constantly challenged; firstly, Devaraj et al. [30] successfully performed an anastomosis in a 0.3 mm vessel and later, the modern evolutions of super-microsurgery left no room for doubt about the feasibility in the use of free perforator flaps in pediatric population. Additionally, the subsequent studies did not confirm the higher tendency for spasm, but rather the opposite based on the incomplete development of the muscular intravascular layer [31]. Nevertheless, it is obvious

that special perioperative care, extremely careful and atraumatic dissection technique are absolutely required when performing a free flap reconstruction in children [32]. Moreover, the special anatomical features and the increased necessity for appropriate adjustment of the peri-operative environmental conditions practically limit the microsurgical approach to more experienced surgeons who have gone a long way in the relevant learning curve (as is the case in the reconstructions included in this study) in order to achieve the optimal results [33]. Table 5 is an attempt to summarize the basic particularities in microsurgery in pediatric compared to adult patients [34].

### Free ALT flap in foot reconstruction

The ALT flap has gradually gained popularity as a first choice reconstructive method since its first description in 1984 by Song et al. [10] to date. Nodal point for the widespread application of the free ALT flap was also the highlighting of its versatility by Koshima et al. [35]. The many advantages of this flap include the long and with good diameter pedicle, the potential of large skin paddle, the adjustment of



n	Study	ALT (n)	Flap type	Perforator type	Operative Time mean (minutes)	Ischaemia time (minutes)	Mean flap size (cm <sup>2</sup> )	Recipient Artery	Anastomosis	Post-op coagulation
1	Merter et al. [9] 2017	1	FC	NR	360	45	54	AT	E-t-E 1 accompanying vein	No
2	Lee et al. [10] 2016	1	FC	NR	NR	NR	84	AT (Dorsalis Pedis)	E-t-E 2nd vein use	NR
3	Acar et al. [11] 2015	11	10 FC 1+ fascia lata *3 sensate	8 MC 3 SC	(Flap raising time=132)	NR	83.2	5 AT 6 PT	8 E-t-E 3 E-t-S Venous Coupler use	Not routinely
4	Hu et al. [12] 2015	25	25 FC + 3-16cm of iliotibial band	NR	313	132	117.01	18 AT 7 PT	In 6 flaps 2nd vein use	Dextran for 5days
5	Marcondes et al. [13] 2015	5	FC	NR	NR	NR	NR	NR	NR	NR
6	El-Gammal et al. [14] 2012	42	FC	37 MC 5 SC	360	127	117.11	38 AT 4 PT	In 9 flaps 2nd vein use	Dextran for 5 days
7	Akcal et al. [15] 2013	4	FC	NR	360	NR	NR	NR	E-t-S artery E-t-E vein	NR
8	Liu et al. [16] 2013	1	FC *Extended with only 1 perforator	SC	NR	NR	252	NR	2nd vein use	NR
9	Napier et al. [17] 2012	2	FC	NR	375	124	NR	PT	E-t-S artery E-t-E saphenous vein	No
10	Arslan et al. [18] 2012	2	FC	NR	NR	NR	NR	NR	NR	NR
11	Gharb et al. [19] 2011	3	FC	6 (3x2) MC	NR	NR	129.67	NR	NR	NR
12	Demitras et al. [20] 2010	5	FC	NR	NR	NR	58.2	4 AT 1 PT	Vessel size 0.5-0.9 mm	NR
	Total	102	26 flaps with extra fascia for tendon repair	51 MC 9 SC (45 NR)	353.6 (28 NR)	104 (32 NR)	119.53 (54-252)	67 AT 20 PT (15 NR)		

(FC= Fasciocutaneous; MC=Muscolocutaneous; SC=Septocutaneous; NR=Not Recorded; AT=Anterior Tibial Artery; PT=Posterior Tibial Artery; E-t-E=End-to-End anastomosis; E-t-S=End-to-Side anastomosis)

**Table 4:** Microsurgical features regarding free ALT reconstruction in trauma in pediatric foot.

flap thickness according to the defect needs, the ability to incorporate muscle (vastus lateralis), bone (ileum), fascia (tensor fascia lata) and nerve (lateral femoral cutaneous), the possibility of simultaneous two team approach and the low donor site morbidity. Especially for the foot defects free ALT flap offers a valuable reconstructive option. The unique architecture of this anatomic area comprises a thin soft tissue cover with multiple underlying tendons and limited neighbouring tissue availability for a local flap. After a traumatic defect in foot a need for durable but thin coverage of exposed tendons, joints, fractures or metalwork immediately emerges.

There is very limited literature describing exclusively the use of free ALT flap in pediatric foot defects. In the present Systematic Review we investigated the use of 102 free ALT flaps for the reconstruction of traumatic foot defects in children, concluding in 95.1% flap survival rate, with only two complete and three partial flap losses due to vein thrombosis. This percentage points out a high reliability of this reconstructive technique and is similar to the flap survival rate in the retrospective review of 40 children by Momeni et al. [36] and higher than that of 26 children by Rinker et al. [37] on the reconstruction of pediatric lower extremity with different types of free flaps. Additionally, it is also higher than other studies that describe the use of muscle or myocutaneous flaps for the reconstruction of lower extremity deficits in children [38,39]. Moreover, in our review 6 flaps necessitated an urgent re-exploration (5.88%) with the relevant rate for lower extremity free

flap reconstruction in pediatric population ranging from 4-29% in the international literature [40-42].

The total complication rate in our Systematic Review was 21.57% with 9 out of the 22 children reported with a hypertrophic scar (total rate of 8.82%). It is indicated by Collins et al. [43] that donor site wound problems in ALT flap use comprise a total percentage of 4.8%, but it is known that hypertrophic scarring tends to be more common in pediatric patients [44]. Because the use of SSG was not consistently reported in all the studies included in our review, we are unable to make a direct correlation of graft use and an eventual hypertrophic scar formation. Nevertheless, graft use in the thigh is known to lead to unsightly and irregularly pigmented scars [45], to result in adhesions between the graft and the underlying fascia limiting the range of motion [46] and to be related to higher risk of hypertrophy and growth limitation [47]. Hence, it should be avoided whenever primary closure without extensive tension is possible, obviating at the same time the risk of a detrimental compartment syndrome which has not been described at the present review but is an actual danger reported in other studies [48]. Tissue expansion before flap harvesting can offer a solution but is not applicable in urgent reconstruction after trauma. Innovative techniques such as DermaClose with continuous external tissue expansion (CETE) offering delayed tension free primary closure should be tested on a wider scale [49,50].

In the vast majority of the cases included in our review the

<b>Particularities in Microsurgery in pediatric comparing to adult patients</b>
Differences at the microvascular level and flap related
Slightly higher flap survival rate and lower replantation success rate
Lower minor complications rate after microsurgical reconstruction
Greater proportion of congenital anomalies (mainly facial and hand) addressed
Smaller vessels necessitating greater magnification (and fine sutures and instruments)
Larger relative size of pedicle vessels
Generally shorter perforator course
High variability in vascular path imposes pre-operative investigation (CT angiogram, Doppler)
Presumable greater vasospasticity necessitates minimal vessel dissection and adventitia excision, and use of local vasodilation (papaverin, lidocain) and locoregional anaesthesia (chlorpromazine)
Bone flaps without intact physis will not elongate normally requiring further adjustments
Myocutaneous flaps usually redound atrophy and fibrosis requiring revision surgery
Denervated muscles prone to fibrosis and contracture needing revision surgery
Usually unscarred anatomy
No concomitant vascular disease (diabetes, hypertension, atherosclerosis, venous stasis)
Greater skin contracture of flap after harvesting
Surgical outcome evident earlier
Differences at the physiological and sociological level
Need for longer duration anaesthetics and rapid post-operative recovery
Higher metabolic needs impose rapid ventilation and increased fluid requirements
Limb vessels mainly affected by sympathetic nerves
Superior sensory return
Increased functional reserves
Better learning skills
Pre-operative assessment requires relaxing environment and optima communication with patient obtained
Parents must be informed in details on the nature of surgery and the post-operative environmental changes and requirements
More careful, better secured and generally larger dressings
Low tolerance to pain and long-time posture fixation
Challenging immobilisation
Sedation and distraction needed for changes of the dressings
Patient and time consuming physiotherapy

**Table 5:** Particular considerations in Microsurgery in pediatric population in comparison with adults.

reconstruction of the traumatic foot defect was delayed for more than 72 h from the time of injury. The timing of extremity defects reconstruction remains a controversial subject. The immediate reconstruction as firstly indicated by Godina [51] has been the protocol procedure for many years. It was later proved by Kolker et al. [52] that the timing has no significant influence on the final outcome with a reported similar success rate for immediate and delayed reconstruction, conclusion that is also consistent with the high success rate in our review.

More than a quarter (27.27%) of the children in our review necessitated a secondary revision surgery for debulking. Generally, a thin flap must be used for foot reconstruction in order to allow unobstructed tendon gliding and ankle movement and also a normal shoe-wear. Primary thinning of the flap may prevent a later revision as indicated by the series of Demitras et al. [22] included in our review; otherwise, with child's growth and the additional fat tissue incorporated in the ALT flap, debulking procedures are really common post-operatively, and can be performed adequately with liposuction with good aesthetic results as Askouni et al. [53] presented in their study.

## Conclusion

The present Systematic Review has attempted to examine the reliability of the free ALT flap as a reconstructive option for traumatic defects in pediatric foot. We have depicted that this technique is safe and results in good functional outcome; however requires high level of skills and experience in its application and often a secondary revision surgery.

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