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Tendon transfer with a microvascular free flap for injured feet in children

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We reviewed 11 patients who had been treated between January 1986 and June 1994 for severe foot injuries by tendon transfer with microvascular free flaps.

Their mean age was 5.6 years (3 to 8). Five had simultaneous tendon transfer and a microvascular free flap and six had separate operations. The mean interval between the tendon transfer and the microvascular free flap was 5.8 months (2 to 15) and the mean time between the initial injury and the tendon transfer was 9.6 months (2 to 21). The anterior tibial tendon was split in five of six cases. The posterior tibial tendon was used three times and the extensor digitorum longus tendon twice.

The mean follow-up was 39.7 months (24 to 126). There were nine excellent and two good results. Postoperative complications included loosening of the transferred tendon (2), plantar flexion contracture (1) mild flat foot deformity (1) and hypertrophic scars (2).

We recommend tendon transfer with a microvascular free flap in children with foot injuries combined with nerve injury and extensive loss of skin, soft tissue and tendon.

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The incidence of pedestrian accidents involving children has rapidly increased and they often sustain tendon and bony injuries to the feet with extensive loss of skin and soft tissue. Skin grafts and microsurgical free flaps are required to replace the defects and tendon transfers and arthrodeses may be indicated. Unlike the adult foot, however, the skin graft may cause joint contracture and deformity because the growth potential of the grafted skin does not match that of other tissues in the child's foot. Arthrodeses may give rise to secondary complications because of restricted ankle movement.

We have therefore reviewed 11 patients who had tendon transfers and a microvascular free flap, to determine the outcome.

Patients and Methods

We reviewed 11 children who had had a microvascular free flap and tendon transfer between January 1986 and June 1994 because of injury in pedestrian accidents. Their mean age was 5.6 years (3 to 8) and there were five boys and six girls. The right foot had been operated on in eight and the left in three (Table I).

There had been wide skin and soft-tissue loss in all patients, with peroneal nerve palsy in two. There was loss of a peroneal tendon in two, of extensor digitorum longus (EDL) and a peroneal tendon in two, of extensor hallucis longus (EHL) in two, EDL in two, and EDL and anterior tibialis tendon in one.

In five patients we performed the microvascular free flap and tendon transfer simultaneously and in the other six the microvascular free flap was done first followed by the transfer at a mean of 5.8 months (2 to 15). The mean time from the initial injury to the microvascular free flap was 6.3 months (1 to 21) and from injury to tendon transfer 9.6 months (2 to 21).

We used a scapular flap in five patients, a parascapular flap in three and a groin flap in three. For the first two we sutured the circumflex scapular artery and its venae comitantes as donor vessels and for the groin flap we used the superficial circumflex iliac artery and its vena comitantes. As recipient vessels, we used the anterior tibial artery and its two venae comitantes in seven patients, the dorsalis pedis artery and its venae comitantes in three, and the popliteal artery and vein in one (Table II). The size of the free flap ranged from 11 × 8 cm to 18 × 16 cm.

Operative technique. Table II gives details of the tendons transferred. A split anterior tibial tendon was used in five patients with varus deformity in whom muscle power was

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Table I. Details of 11 patients who had tendon transfer

Case	Gender	Age (yr)	Flap*	Tendon transfer (TT)†	Interval between flap and TT	Deformity	Cause‡	Insertion site	Combined operation	Follow-up	Result	Complication
1	F	3	FVSF	STA	15 mth	Varus	ED and peroneal tendon loss	4th metatarsal base		10.5 yr	Excellent	Loosening TT
2	F	5	FVSF	TP	Simult	Equinovarus	PNP	Lat cuneiform	HCL§	25 mth	Excellent	Hypertrophic scar on donor site
3	M	4	GF	STA	2 mth	Drop foot	ED and PB tendon loss	Lat cuneiform	HCL	31 mth	Excellent	Loosening TT
4	M	6	FVPF	STA	Simult	LOM¶	Extensor tendon loss	EHL		24 mth	Good	Plantar flexion contracture
5	F	5	FVPF	TP	2 mth	Drop foot	PNP	Lat cuneiform	HCL	35 mth	Excellent	Hypertrophic scar on donor site
6	M	6	GF	2nd EDL	Simult	Drop great toe	EHL loss	EHL		31 mth	Excellent	None
7	M	6	GF	2nd EDL	Simult	Drop great toe	EHL loss	EHL		33 mth	Excellent	Partial necrosis of flap
8	M	6	FVSF	TA	Simult	Varus	Peroneal tendon loss	Cuboid		56 mth	Excellent	None
9	F	8	FVPF	STA	3.5 mth	Drop foot	Extensor tendon loss	Cuboid		26 mth	Excellent	None
10	F	6	FVSF	STA	9 mth	Varus	Peroneal tendon loss	Cuboid		26 mth	Excellent	None
11	F	7	FVSF	TP	3 mth	Equinus	TA, EDL, EHL tendon loss	Intermediate cuneiform	HCL	24 mth	Good	Mild flat foot deformity

* FVSF, free vascularised scapular flap; FVPF, free vascularised parascapular flap; GF, groin flap;
† TA, tibialis anterior; TP, tibialis posterior; STA, split tibialis anterior; EDL, extensor digitorum longus
‡ EHL, extensor hallucis longus; PNP, peroneal nerve palsy; ED, extensor digitorum; PB, peroneus brevis
§ heel cord lengthening
¶ limitation of movement

Table II. Operating techniques

	Number
Microvascular flap	
Types of flap	
Scapular	5
Parascapular	3
Groin	3
Types of recipient vessel	
Anterior tibial artery	7
Dorsalis pedis artery	3
Popliteal artery	1
Tendon transfer	
Tendon used	
Anterior tibial tendon	
Split	5
Complete	1
Posterior tibial tendon	3
2nd extensor longus tendon	2
Fixation methods	
Tendon to bone	8
Tendon to tendon	3

normal. The lateral half of the anterior tibial tendon was divided at the insertion site, then rerouted through the subcutaneous tissue and attached to the cuboid, the lateral cuneiform, the base of the fourth metatarsal and the remnant of EHL according to the degree of deformity and functional loss.

In three children the tendon of tibialis posterior was exposed and divided at its insertion, then rerouted through the interosseous membrane, subcutaneously to the dorsum of the foot and attached to the lateral or central cuneiform. In two children with loss of EHL, the EDL tendon of the second toe was cut at the level of the EHL tendon injury, then a tendon-to-tendon suture was done between the distal end of the severed EDL tendon of the second toe and the ruptured distal stump of the EHL tendon. Extension of the second toe was not impaired because of the continued action of the short extensor.

The sites of insertion of the tendon transfer were the cuboid in three patients, the lateral cuneiform in three, the intermediate cuneiform in one, the base of the fourth metatarsal in one and the distal stump of EHL in three.

A slightly overcorrected position was maintained postoperatively in a short- or long-leg plaster cast for six weeks in those with bone attachment and for three weeks in those with tendon-to-tendon attachment. After immobilisation, the range of movement of the ankle was gradually increased. In four patients severe contracture of tendo

Table III. Criteria of Srinivasan et al[1]

Grade	Active dorsiflexion	Range of active movement (degrees)
1	Above the neutral (right-angle) position	>25
2	Up to but not beyond the right angle	10 to 25
3	Failure to regain dorsiflexion up to the right angle	<10

Table IV. Grading of tendon transfer in 11 patients

	Grade		
Criteria	**1**	**2**	**3**
Active dorsiflexion angle	9	2	0
Range of active movement	9	2	0

Achillis required lengthening. The mean follow-up after tendon transfer was 39.7 months (24 to 126).

Results

For evaluation of the results we used the method of Srinivasan, Mukherjee and Subramaniam[1] which uses the active dorsiflexion angle and the range of movement of the ankle and great toe. The angle was checked at a position of 90° flexion of the knee with the foot in a freely dropped position. There were three grades as follows: 1) active dorsiflexion above the neutral (right-angle) position; 2) active dorsiflexion up to but not beyond a right angle; and 3) failure to reach a right angle (Table III). Nine patients were in grade 1, two in grade 2, and none in grade 3 (Table IV).

For range of active movement grade 1 indicated more than 25°, grade 2 10 to 25°, and grade 3 less than 10°. There were 9 children in grade 1, two in grade 2, and none in grade 3 (Table IV).

The total score was calculated by adding the subjective assessment, walking ability, correction of the deformity and muscle power. There was an excellent result in nine patients in whom more than three indices were acceptable and who also had grade-1 active dorsiflexion and active range of movement. Good results were obtained in two with two acceptable indices. Thus, satisfactory clinical results were obtained in all patients.

There were postoperative complications in seven patients, three of whom had tendon transfer and four a microvascular free flap. The complications resulting from tendon transfer included loosening of the transferred tendon in two cases, plantar flexion contracture in one, and mild flat foot deformity in one. We tightened the loose tendon with good results. The plantar flexion contracture required physiotherapy and an ankle foot orthosis while the mild flat foot deformity needed a valgus arch support. The complications of the microvascular free flap included partial necrosis of the grafted free flap in one patient and a hypertrophic scar of the donor site in two. The necrotised free flap was removed and skin grafting performed with good results. In the patient with hypertrophic scarring, scar revisions gave a satisfactory appearance.

Case report. A 2.5-year-old girl sustained a crush injury of the right foot and ankle under the wheel of a heavy truck. There was skin and soft-tissue loss of 10 × 7 cm on the dorsum with open fractures, partial loss of the first to the fifth metatarsal bones, and segmental loss of the first to the fifth extensor and peroneal tendons. There was also an open fracture of the calcaneus (Fig. 1). The dorsalis pedis pulse was absent, but the posterior tibial artery was palpable.

After two debridements, the second and third phalanges were amputated. A scapular flap of 13 × 8 cm (Fig. 2) was grafted on the dorsum of the foot to cover the skin and soft-tissue defect. We connected the circumflex scapular artery and two venae comitantes to the anterior tibialis artery and venae comitantes, and performed open reduction and internal fixation with Kirschner wires for the metatarsal fractures.

During follow-up, we observed inversion of the ankle on dorsiflexion. There was weakness of dorsiflexion and a decreased range of movement due to segmental loss of peroneal tendons. The patient was readmitted 15 months after the initial injury for a split tibialis anterior tendon transfer to the base of the fourth metatarsal. Six months

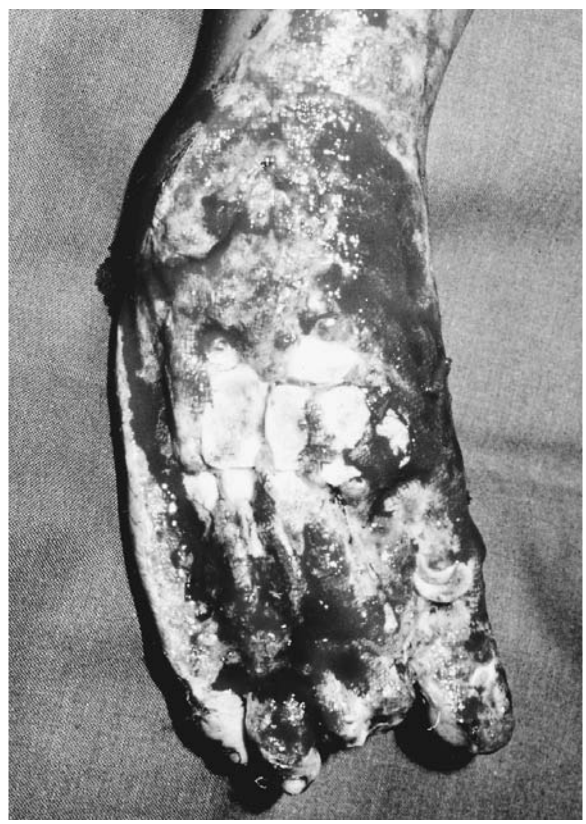

Fig. 1

The right foot of a 2.5-year-old girl with extensive loss of soft tissue, toe extensors and peroneal tendons, and macerated tarsal bones. The second and third toes had been amputated.

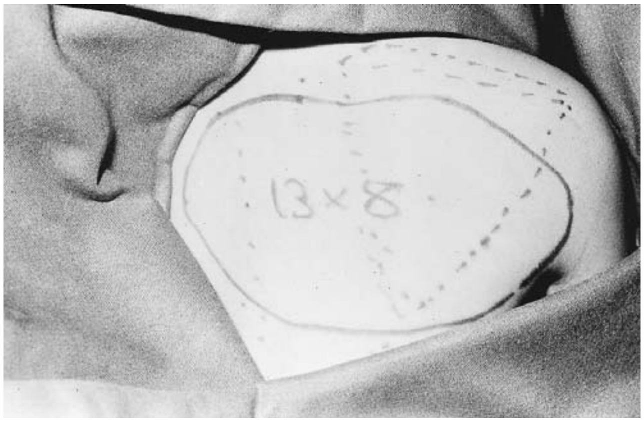

Fig. 2

The free vascularised scapular flap was designed on the right scapular area 13 × 8 cm in size. The medial margin was beyond the midline.

after the tendon transfer, loosening of the transferred tendon was diagnosed and we tightened it to strengthen dorsiflexion. There was no necrosis of the flap or plantar flexion contracture. At final follow-up, the inversion of the ankle on dorsiflexion had been corrected and the range of movement of the ankle was 15° of dorsiflexion and 60° of plantar flexion (Fig. 3). The result was grade 1 according to the criteria of Srinivasan et al.[1]

Discussion

Since Jacobson and Suarez[2] succeeded experimentally in suturing a vessel of 1 mm diameter using a microscope in 1960, the use of the microvascular free flap has developed rapidly for the reconstruction of wide soft-tissue defects. The advantages are that it requires only a one-stage operation, early movement of the injured site is possible, the grafted skin and subcutaneous tissue are durable, a vascularised bone graft can be performed simultaneously and primary closure is usually possible at the donor site. The disadvantages are that it is difficult to perform, time-consuming, and necrosis of the free flap may occur because of obstruction of a vessel during or after the operation.[3]

Physiologically, children differ from adults in that the diameters of vessels are larger than expected, they recover more quickly, and the re-education of function and sensory appreciation is a minor problem.[4]

The advantages of the scapular flap are that it is a large free flap which uses the circumflex scapular artery, the anatomy of the vessels is consistent without variations, there is no hair, and the vessels are large enough to suture. It is almost always possible to close the donor site and there is no functional impairment. The disadvantages are that the flap may be too thick and there is no sensory nerve supply.[5-9] To obtain as large a size as possible and to minimise the disadvantages Nassif et al[10] introduced the parascapular free flap. We performed five scapular flaps and three parascapular flaps. Our largest flap was 18 × 16 cm. We achieved satisfactory clinical results without any significant complications except for two hypertrophic scars at the donor site.

An inguinal flap uses the superficial or deep circumflex iliac artery system. It is a large flap and primary closure of the donor site is possible. The iliac-bone graft can be taken simultaneously and there is no hair in the flap. If it is too thick, however, it may not blend with the surrounding tissue because of its lighter skin colour. In addition, the donor vessels are short and their diameter is small. There is no sensory nerve.[3,8,11-13] We performed three groin flaps and had satisfactory clinical results despite one case of partial skin necrosis.

Postoperative conversion of muscle from the stance phase to that of the swing phase was imperative in tendon transfers of the posterior tibial tendon, and most patients did well subjectively but not in the rhythmic movement of walking. Re-education was therefore necessary for conversion of the posterior tibial tendon to the swing phase.[14-16] No patient had difficulties in walking because of this.

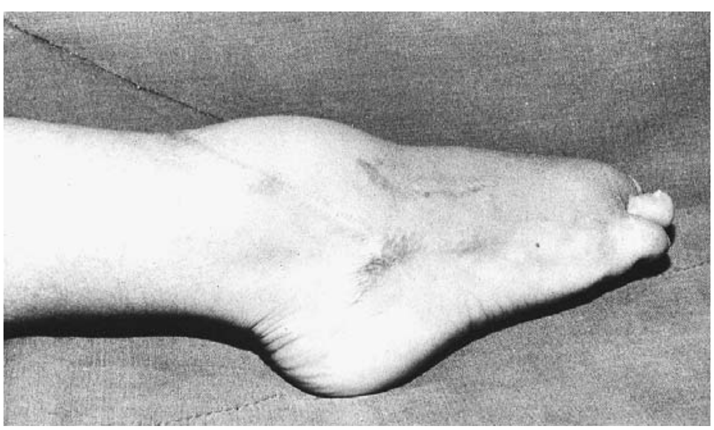

Fig. 3a

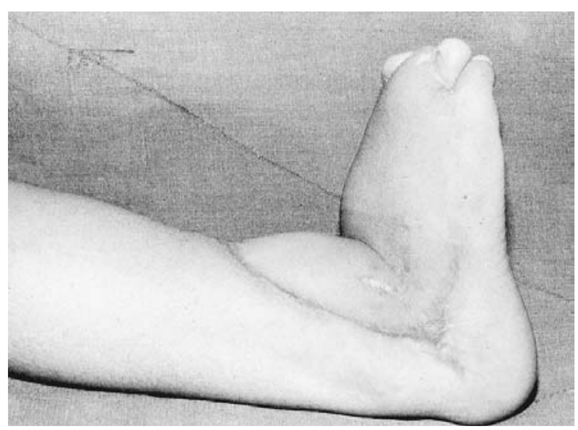

Fig. 3b

After tendon transfer, inversion of the right foot was corrected and active range of movement was improved. Active dorsiflexion of the ankle was to 15° and plantar flexion to 60°.

We used the split anterior tibialis tendon in five patients with normal muscle power and obtained excellent clinical results with stability of the foot in all.[17] We found that the stability of the foot and ankle was better with split transfer than total transfer of the tendon.[18]

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