



## Vascularized Fibular Transfer in Longstanding and Infected Large Bone Defects

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The reconstruction of large bone defects in the infectious environment is still a big challenge for limb salvage because of disturbance in bacterial flora, bacterial resistance and limitation of blood supply at scarred tissue. This retrospective study was to evaluate long-term outcomes in patients who were performed vascularized fibular transfers for treatment of large bone defects in the infectious environment.

The review included 26 patients with an average age of 27 years old. Bone defects were located at the arm in 1 patient, the forearm in 2 patients, the thigh in 6 patients and the leg in 17 patients. The cause of the bone defects included high-energy trauma in 14 cases, chronic osteomyelitis in 7 cases, infected non-union in 5 cases. All patients had had several previous operative procedures.

The average length of fibular vascularized graft was 16.6 cm (range, 10-22 cm), and the average size of the associated fasciocutaneous component in 16 patients was 3.6 × 8.5 cm. Three patients had partial necrosis of skin paddle. Three patients, who were stabilized by screw and external fixator, had an infection at the distal part of the fibular graft and pin tracts. 25 fibular grafts (96%) showed complete bone union.

This review has showed that the vascularized fibular transfer can be effective for management of large segmental bone defects in the infectious environment.

**Keywords :** Vascularized fibular transfer, large bone defects, osteomyelitis and infected non-union.

### INTRODUCTION

The reconstruction of large bone defects in the infectious environment is still a challenge for limb

salvage because of disturbance in bacterial flora, bacterial resistance, insufficient bone debridement and limitation of blood supply in scarred tissue (3). Several reconstructive procedures have been attempted, but a biological option was to use autogenous bone. Donor autogenous bones that were used for vascularized bone graft include the fibula, ilium, scapula, and rib. But the vascularized fibular graft is a well-recognized donor of vascularized bone (10,18,19).

Taylor *et al* published the first successful description of vascularized fibular graft in 1975 (24). Yoshimura *et al* described the first use of vascularized fibular graft with skin paddle in 1983 (26). Vascularized fibular graft has important advantages to the mechanism of bone healing by maintaining

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the viability of the graft and strengthening mechanical properties allows for faster union and graft hypertrophy irrespective of the avascular and infectious bed (10).

The purpose of this retrospective study was to evaluate long-term outcomes with patients in whom we performed vascularized fibular transfers for treatment of large bone defects in the infectious environment.

**PATIENTS AND METHODS**

The review included 26 patients (18 males and 8 females) had large bone defects caused by Gustilo’s grades IIIB or IIIC open fracture, chronic osteomyelitis, or infected non-union between 1999 and 2010. Bone defects (larger than 6 cm were located at the arm in 1 patient, the forearm in 2 patients, the thigh in 6 patients and the leg in 17 patients. The cause of the bone defects included high-energy trauma in 14 cases, chronic osteomyelitis in 7 cases, infected non-union in 5 cases. All patients had had several previous operative procedures : 3 patients had a bone loss associated with a very large soft-tissue defect, they were previously covered soft-tissue defect before the fibular transfer : One pedicled abdominal flap at the forearm and two free lastissimus dorsi flap at the leg (Table I). The delay between the accident and vascularized fibular transfer ranged from 4 months to 5 years.

**Operative technique**

Two teams operated simultaneously, one harvesting the fibular graft, and the other preparing the recipient

site. The vascularized fibular graft was assessed using a lateral approach described by Gilbert (9). An angiography was carried out in case of history of severe trauma and soft-tissue contracture.

*At the donor site:* Doppler sonography marked preoperatively the pedicle vessels and cutaneous perforators. If it is necessary, the graft was harvested by incorporating the skin island to provide soft-tissue coverage and to allow postoperatively monitoring of the graft. The length of fibular graft depends on the bone defects, which was usually the length of bone defects minimum plus 4 cm. The distal cut had to more than 8 cm above the lateral malleolus.

*At the recipient site:* Infected and devitalized tissue was radically debrided, all contracted scar and inflammatory tissue was thoroughly excised and both proximal and distal parts of the medullary canal were resected and reamed until good vascularized bone was found. Samples of all tissue and bone were sent for bacterial cultures. The vessels of the recipient site were carefully dissected and exposed. Impacting both ends of the graft into the medullary cavity of the recipient bone was required. Bone fixation using screws, plate, Kirschner wires or external fixator was then achieved depending on the individual requirements of the particular defect. The peroneal vessel attached to the fibular graft was anastomosed to the recipient vessel with 9.0 interrupted nylon sutures using the microsurgical technique.

Clinical examination including color, capillary refill and bleeding were carefully be observed. Doppler sonography was used if necessary. IV antibiotics were given according to the microbiological sensitivity test. The patient was followed-up every 3 months in the first year and every 6 months from 1 year to 3 years, continuously followed up until full bone union, determined by clinical examination and radiographs.

Table I. — Initial Treatment before reconstruction.

Position	Humerus	Radius & Ulna	Femur	Tibia
Initial treatment (n)				
Internal plate (3)			1	2
Debridement + EF (13)			5	8
Serial debridement +/- VAC (7)	1	1		5
Pedicled abdominal flap (1)		1		
Free lastissimus dorsi flap + EF (2)				2
<b>Total</b>	<b>1</b>	<b>2</b>	<b>6</b>	<b>17</b>

EF : External Fixator ; VAC : Vacuum Assisted Closure.



**Fig 1.** — Radiograph of 38-year-old male patient had an atrophic and infected non-union associated with soft-tissue contracture of the left tibia. Patient had undergone four-time surgery for osteomyelitis after open fracture by a motorcycle accident 5 years ago (a). Radiograph of vascularized fibular transfer with skin paddle and stabilization by bridged plate (b). Patient had a bone healing in radiograph (c) and restored the normal function of the leg at 2 years follow-up (d).

Table II. — Methods of the fibular graft stabilization into the recipient bone.

Stabilization (n) \ Position	Humerus	Radius & Ulna	Femur	Tibia
Kirschner wire (3)	1	1		1
Transcortical screws (3)				3
Bridge plate (11)		1	5	5
External fixator & screws (9)			1	8
<b>Total</b>	<b>1</b>	<b>2</b>	<b>6</b>	<b>17</b>

Differences between groups of trauma, osteomyelitis and chronic non-union at the table III were assessed using Fisher's exact test and Anova test. A  $p$  value  $< 0.05$  was considered statistically significant. Statistical analyses were performed using SPSS version 18.0 (SPSS Inc., Chicago, IL).

## RESULTS

The average age of these patients was 27 years old (range, 2-57 years old). The average length of bone defect was 10.8 cm (range, 8-16 cm). The average length of the fibular vascularized graft was 16.6 cm (range, 10-22 cm); 16 patients with soft-tissue contractures required a fibular graft reconstruction with skin paddle, and the mean size of the associated fasciocutaneous component was  $3.6 \times 8.5$  cm. Fibular grafts were stabilized to the recipient bone by Kirschner wires, transcortical screws,

bridge plates or external fixators associated with transcortical screws (Table II).

There were no intraoperative complications. Three patients had postoperatively partial skin paddle necrosis that needed wound care and a secondary skin graft. In three patients, stabilized by screws and external fixator, an infection was present at the distal part of the fibular end and a pin tract infection. All of them were treated with debridement, screws removal, pin tract transposition and antibiotics. Twice infection was controlled and the cancellous bone autograft procedure was carried out after 3 months. But one was still a deep infection and patient refused any further treatment and the upper third of the leg was amputated.

All remaining 25 bone grafts survived. No patient had a functional problem of the donor site. (Fig. 1, 2) Only one patient, however, complained about intermittent ankle joint pain when he walked



**Fig 2.** — Radiograph of 28-years-old male patient had segmental bone defect at the left femur caused by open fracture and stabilized temporarily with an external fixator (a). Postoperative radiograph showed a femoral reconstruction with vascularized fibular transfer and stabilization by bridge plate (b). Patient had a bone healing in radiograph at 3 years follow-up (c).

**Table III.** — Characteristics between groups of trauma, chronic osteomyelitis and infected non-union.

Characteristics \ Group	Trauma (n=14)	Osteomyelitis (n=7)	Infected non-union (n=5)	p value
Positive bacterial cultures	10	7	5	0.308
Previous flap coverage	2	1	0	1.000
Bony gap (cm)	8.2	11.9	6.8	0.001
Post-op infection	2	1	0	1.000
Primary bone union	12	6	5	1.000
Delay bone union	2	0	0	0.692
Failure	0	1	0	0.462
Long-term malunion	0	1	0	0.462

a long distance during the first six months follow-up, but this pain was relieved after one-year follow-up. Normal bone union occurred in 23 patients with a mean healing time of 3.5 months (range, 2-5 months). Delayed bone union in 2 patients with a mean healing time of 8 months (range, 7-10 months). One 9-year-old patient had an angular deformity and shortening of the leg 5 years after the fibular transfer. When he was 15 years old, he was operated for correcting the deformity and lengthening of the tibia utilizing an Ilizarov procedure (Table III).

## DISCUSSION

Our study showed that this vascularized fibular graft has been successful in reconstruction of large

bone defects in the infectious environment. The healing mechanisms of a vascularized bone graft are distinctly different from the other procedures, restoration of the physiologic blood flow occurs immediately at the completion of the microvascular anastomosis. This circumstance retains osteoblastic and osteoclastic potential for primary bone healing as in a simple fracture (1). Heitmann *et al* reported that, vascularized bone grafts remain alive, do not resorb, maintain their structural characteristics, and increase its structural strength through hypertrophy (6). This graft allows surgeons to accomplish a series of extensive debridement of infected and devitalized both tissue and bone back to bleeding ones regardless how much defect will be. By immediate blood supply, this graft brings also antibiotic and immune components to the recipient site to

control the infection (3,7,9). Furthermore, the fibular graft provides adequate length up to 26 cm, the predictable anatomy, mechanical strength and hypertrophy potential. Therefore the vascularized fibular graft is presented as the most suitable autograft for restoring the large segmental bone defects, involving high-energy trauma, chronic osteomyelitis and infected non-union in both upper and lower extremities (1,6,9). In addition, the fibular graft has the ability to be combined with a skin island, can be used to solve complex problems in bone and soft-tissue defects (6,7,17,18,26).

The study reported no evidence of the any resorption of the vascularized fibular graft. 25 fibular grafts (96%) showed complete bone union, this compares favorably with other authors. Falder *et al*, success rate was 91% (29 over 32 grafts) (5), and Soucacos *et al*, graft healing was achieved in 92% in the upper limb (37 out of 40) (23).

One of the most important conditions for graft healing is the very strong fixation of the fibular graft. This fibular graft acts as a biological intramedullary nail, and cortical screws that fixed through the fibula and the host bone at both ends, play a role of interlocking screws (27). Kirschner wires, bridge plate or external fixator supported the fibular graft stabilization. But Kirschner wires were used only in the children. In the first period of our series, external fixators were continuously utilized for graft stabilization in the lower limb. However, in the long-term, pin tract infections can occur. For this reason, we tried to use internal fixation for the entire femoral length. As much as possible, we used the same technique for the tibia.

Our trauma group included 14 patients who had a high risk of infection or had been extensively debrided. The fibular transfer was performed in a second stage (Fig. 2). This well-vascularized composite graft permitted resection of all infected tissue and devitalized bone down to a bleeding zone. The amount of soft-tissue or bone that had to be removed was not limited. Our goals of reconstruction by vascularized fibular graft were filling the dead space, minimizing the deep tissue infection and preventing the development of osteomyelitis (9,27).

Twelve patients were failures of several previous procedures. The local situation of the recipient site

showed many complications such as: bone atrophy, infectious environment and avascular soft-tissue contracture. By increasing the vascularity and the blood supply of the fibular graft, limb salvage could be obtained with a single surgical procedure (Fig. 1). We had 11 bone unions and 1 failure in this group. Yajima *et al* obtained bony union in 18 of 20 cases (25). The disadvantage of our study is that the fibular graft is smaller than the host bone, especially in the femur (17). One of 6 patients, who had a short femoral bone defect, was treated using the double-barrel technique. But the remaining 5 patients, we could not perform that technique and needed to wait a long time before hypertrophy allowed complete weight bearing.

## CONCLUSION

This study has showed that the vascularized fibular transfer can be effective for management of large bone defects in the infectious environment. Many of these patients had been treated for many years; especially the ongoing infection, osteomyelitis, insufficiently large debridement and non-union were the causes for failed bony union. The advantage is the possibility to restore the length of the bone with a single procedure and provide a return to normal life for the patient. Therefore this fibular transfer remains our reconstructive choice for limb salvage.

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