

# Reconstruction of posttraumatic long bone defect with free vascularized bone graft

Good outcome in 48 patients with 6 years' follow-up

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Submitted 00-07-03. Accepted 01-01-07

**ABSTRACT** – We analyzed our clinical results in 48 patients (40 men) treated during 1990–1993 with free vascularized bone-graft reconstruction for bone defects, the follow-up being an average 6 (5–8) years. The bone defects were located in the femur (10), tibia (32), humerus (2), and forearm (4). We performed 41 fibula transfers, 4 iliac transfers, and 3 rib transfers in these patients. 3 patients required early revision surgery due to venous thrombosis. The average time needed for radiographic bone union was 4.2 months. Bone transfers to the lower extremity showed significantly more hypertrophy than those in the upper extremity. The functional outcome was good in 43 patients.

distant transfer of revascularized bone grafts by immediately anastomosing the nutrient vessels in well-established (Taylor et al. 1975). Such grafts retain their intrinsic blood supply and preserve viability so that healing occurs by simple fracture union rather than “creeping substitution” after transfer (Weiland et al. 1984). Therefore, bone union and graft hypertrophy may be hastened, and the viable cortical structure can provide better mechanical support (Jupiter et al. 1987, De Boer and Wood 1989). We analyzed our series of patients who received free vascularized bone grafts for posttraumatic long bone defects exceeding 6–8 cm.

With conventional bone-grafting procedures, most failures occur in cases with bone defects exceeding 6–8 cm because of the slow and incomplete neovascularization of the graft (Makley 1985). A non-vascularized conventional bone graft is probably never replaced by completely healthy bone tissue, but exists as a mixture of necrotic and viable bone with reduced strength (Weiland 1981).

Muscle pedicle bone grafts appear to retain appreciable amounts of viable tissue (Judet and Patel 1972). Improved results using such grafts have been noted, particularly in bony nonunions that are surrounded by poorly vascularized soft tissue (Chacha 1984). However, the length of its vascular pedicle limits the use of a muscle pedicle graft (Bieber and Wood 1986).

The current advance in microsurgery, with free-

## Patients and methods

From January 1990 through December 1993, 50 patients received a free vascularized bone graft for the reconstruction of posttraumatic segmental long bone defects in our Institute. 2 patients were excluded. One of them was a foreign worker who returned home 2 years after surgery. The other died in a traffic accident 15 months after surgery. The remaining 48 (40 men) patients were followed for a mean 6 (5–8) years. Their mean age was 48 (15–62) years. The mean length of the bone defect was 10.2 (6.5–19) cm. The mean duration from trauma to reconstruction was 4.6 months (3 days–5 years). The indications for vascularized bone transfers included: (1). immediate reconstructions of an acute traumatic bone loss after severe open fractures in 10 patients; (2). delay in free bone graft

for posttraumatic long segmental bone loss in 18 patients; and (3). repair of the segmental bone defect after debridement and resection of infected bony tissue for treating osteomyelitis in 20 patients. The bone defects were located in the femur (10), tibia (32), humerus (2), and forearm (4). 41 patients had vascularized free fibula bone transfers, 4 had iliac osteocutaneous bone transfers, and 3 combined latissimus dorsi muscle, serratus anterior muscle, and vascularized ribs transfers. In 41 patients who received free fibula bone transfers, 35 patients had fibula osteocutaneous flap transfers and the other 6 had fibula osteomuscular transfers (fibula bone with flexor hallucis longus muscle attached to it). In 35 patients who received fibula osteocutaneous flap transfers, 30 had 1 artery and 2 vein anastomoses, and the other 5 patients had 1 artery and 1 vein anastomosis. Of these 48 patients, internal fixation was performed in 5, external fixation in 11, and combined internal and external fixation in 32 patients. We routinely added an autogenous cancellous bone graft at the junction between transferred bone and recipient bone.

All transfers were planned and performed by our microsurgical team staff. Experienced nursing personnel monitored the postoperative care and flap survivals very carefully. We evaluated the skin color and perfusion in 39 patients who received osteocutaneous flap transfers (35 with fibula, and 4 with iliac). For 9 patients who received osteomuscular flap transfers (6 fibula, and 3 ribs), we evaluated the color, perfusion, and temperature of the flap muscle. In upper extremity lesions, passive and active joint motion were started 3–5 days after microsurgery. In lower extremity lesions, patients were allowed isometric muscle exercises and getting out of bed 5–7 days after surgery. Non-weight-bearing gait training was started in the second week postoperatively. Subsequent physical therapy and partial or full weight bearing were scheduled after discussion with physical therapists and surgeons. The SF-36, a 36-item short-form generic health status survey, was used for follow-ups (Ware 1992). Anteroposterior and lateral radiographs were taken at 3-week intervals after surgery. The presence of an indistinct or absent osteotomy line, or the presence of bridging bony trabeculae was defined as radiographic bone union of the grafted and recipient bone (Han et al. 1992, Minami et al. 2000).

When radiographic bony union was uncertain, we also used tomograms for evaluation. The external fixator was removed when union was seen radiographically, and a brace was applied until the fibula was solidly incorporated, at which time full weight bearing was commenced. The radiographs were also evaluated for graft hypertrophy, stress fracture and other complications. We assessed hypertrophy of the fibula graft with DeBoer and Wood's method (1989), using a graft hypertrophy index (In) as

$$In = \frac{G2/R2 - G1/R1}{G1/R1} \times 100\%$$

Where G1 = graft meter at proximal junction at surgery, R1 = host bone diameter at the proximal junction at surgery, G2 = graft diameter at proximal junction at follow-up, R2 = host bone diameter at the proximal junction at follow-up

A positive index value indicates hypertrophy and a negative value graft atrophy. We recorded hypertrophy only if the graft index had increased by more than 20%. We used the student t-test to evaluate the difference in hypertrophy index.

## Results

The primary success rate of our free vascularized bone grafts was 93.7% (45 of 48 cases). The mean duration of surgery was 6.2 (4.5–10) hours. The average blood loss was 0.9 L, and average blood transfusion 5.7 units of packed red blood cells. The average time taken for radiographic bone union was 4.2 (3–9) months, and was similar in all locations. Full weight bearing was not permitted in lower extremity-reconstructed patients even at the time of radiographic bony union. In patients who underwent a tibial reconstruction, full weight bearing was started at an average of 7.5 (6–14) months, after solid union and hypertrophy of the grafted bone. Patients who underwent a femur reconstruction needed an average of 8.2 (6.5–15) months to achieve solid bone union and hypertrophy for full weight bearing. Hypertrophy of the bone grafts was noted in the lower extremities in all 42 cases, and in the upper extremity in 4 of the 6 patients. The mean graft hypertrophy index in the lower extremity was 82%, and in the upper extremity 38%. Bone transfer over a lower extremity showed significantly

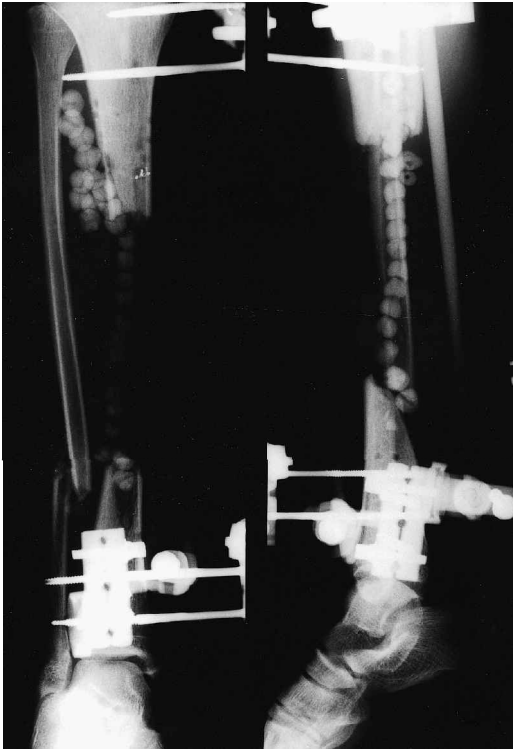


Figure 1. A 45-year-old man, with an open tibia fracture, developed a severe infection in his right tibia which caused a segmental bone defect (14 cm) after debridement and bead-pouch technique.

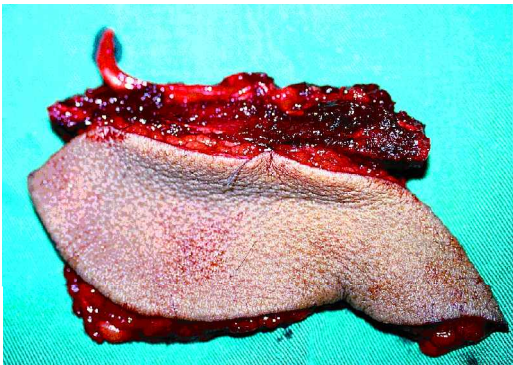


Figure 2. A free vascularized fibular osteocutaneous flap was harvested from his left lower limb for right tibial reconstruction.

more hypertrophy than that over an upper one ( $p = 0.001$ ). The SF-36 score was more than 75% in 43 patients, 50–75% in 3, and less than 50% in 2 who had a postoperative infection and previous history of posttraumatic osteomyelitis for more than 3 years.



Figure 3. The graft showed solid union after 2 years' follow-up, and 73% hypertrophy.

### Complications

3 grafts needed early revision microsurgery due to venous thrombosis detected by skin inspection. All 3 patients had long bone defects due to osteomyelitis, and were reconstructed with free fibular osteocutaneous transfers in whom we used one artery and one vein anastomosis. All of these flaps were saved by reoperation with removal of the thrombosis and one more venous anastomosis. However, 2 of them developed a minor complication with partial flap losses over the skin of the fibular osteocutaneous flap. 5 patients with a postoperative infection, had previously been treated for osteomyelitis. Nonunion occurred in 3 patients, in 2 at the proximal junction and in 1 at the distal junction. 1 of these patients was treated with a secondary cancellous bone graft 5 months after the bone transfer, and his femur healed 9 months after microsurgery. The other 2 patients received secondary cancellous bone grafts for their tibial nonunions 4 months after the bone transfers. Both of them achieved radio-



Figure 4. A 31-year-old man suffered from an open left humerus fracture in a high falling injury 1 year ago. During 1 year, he was operated on 8 times, resulting in a 10 cm infected bone defect, loss of arm function, and severe deformity. The radiograph showed marked bone loss, and disuse osteoporosis of the left humerus.

graphic bone union 7 and 8 months after microsurgery.

4 patients fractured their vascularized fibula bone grafts 9–16 months after surgery. The fractures were plated and healed after 16–22 months. Transient peroneal palsy over the donor leg was noted in 2 patients with fibula transfers, who recovered within 3 months. Postoperative contracture of the flexor hallucis longus muscle occurred in 2 patients, who were treated with physical therapy and had an acceptable gait.

## Discussion

The advantage of vascularized bone grafts is the combination of viability of cancellous grafts with stability of cortical grafts, along with their own nutrient blood supply intact. Another method for reconstructing bone defects, especially in femur

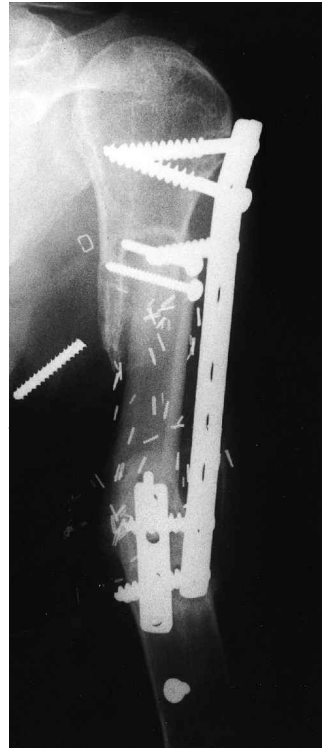


Figure 5. Free vascularized fibular osteocutaneous graft with solid union, and 29% hypertrophy at 3 years' follow-up.



Figure 6. Good postoperative function at 5 years' follow-up.

and tibia, is the bone distraction technique (Ilizarov 1989, Paley et al. 1989). The advantages of distraction osteogenesis include its ability to reconstruct a long bone defect, repair nonunion, correct deformity, and lengthen a limb. The drawbacks

are infection of the wire site, docking site non-union, and prolonged use of the external fixator (Carrington et al. 2000). When patients are unsuitable candidates for microsurgery; because of severe arteriosclerosis of the vessel, old age (more than 65 years), single-vessel leg after previous trauma, or heavy smoker, the bone distraction method can be used to bridge bone defects instead of vascularized bone grafts. Patients with problematic bone donor sites, such as concomitant chest trauma with multiple rib fractures or bilateral leg trauma with fractures both fibula are also candidates for distraction osteogenesis.

The vascularized bone transfer can hypertrophy. De Boer and Wood (1989) reported that definite hypertrophy (20% width enlargement) was present in 43% of their cases within 1 year and 80% within 2 years. The cause of hypertrophy is not clear. Ikeda et al. (1992) and Mizumoto et al. (1986) considered mechanical loading important. However, Fujimaki and Suda (1994) demonstrated hypertrophy of the transferred fibula without weight bearing. We found more hypertrophy in the lower than in the upper extremities, which may suggest that weight bearing is importance.

Comparison with the literature is difficult because most reports are case reports which emphasize the success rather than the limitations and complications of free vascularized bone transfers. Weiland et al. (1983) reported 32 fibula transfers with a successful clinical outcome in 28 cases. Buncke et al. (1977) reported 5 cases using vascularized rib transfers as osteocutaneous free flaps with primary success in 3. Han et al. (1992) reported a large series of 160 patients with free iliac crest (28) or fibula transfer (132). The indications for the procedure were a skeletal defect including nonunion, resulting from a tumor resection, trauma, osteomyelitis, or a congenital anomaly. In the entire series, the rate of union after the primary procedure was 61% and the overall union rate at final follow-up examination (including the patients who had a secondary procedure) was 81%. The results were less satisfactory in patients who had had the reconstruction for bone loss due to osteomyelitis.

Hou and Liu (1992) reported a series of 5 cases with 'two-strut' free vascularized fibula graft to reconstruct a bone defect in the femur. The "two-strut" bone graft means performing osteotomy an

in the middle of the transferred fibula to increase the contact area and strengthen the vascularized bone graft. All the bone grafts healed on an average of 7 months. Wei et al. (1997) had reported 17 cases who received a free fibula osteocutaneous graft for reconstruction of segmental femoral shaft defects. The average time for union was 8 months. In our series, the average time needed for radiographic bone union was 4.2 months, which was similar to that reported by Minami et al. (2000). One reason for earlier bone union in our series might be the routine use of a local cancellous bone graft, early protected-weight bearing, and a comprehensive rehabilitation program. As regards clinical solid union and hypertrophy of grafted bone that permit full weight bearing, our series showed about the same results as Hou and Liu (1992) and Wei et al. (1997).

The fibula, iliac crest and rib are the most frequently employed donor sites for free bone transfers. The structural characteristics of the fibula make it more suitable to reconstruct long bone defects than the rib. The principal advantage of the free rib graft is its ability to transfer adjacent skin, muscle, and nerves. The rib is curved and malleable, and well suited for mandibular defects. The curvature of the iliac crest usually limits its use to defects of less than 10 cm and it is probably associated with a higher donor-site complication rate, such as incisional iliac hernia (Han et al. 1992). This is why most of our defects were reconstructed by using free fibula transfers (41 in 48 cases). However, the donor areas of the vascularized fibula bone grafts have their problems, such as peroneal palsy, contracture of the long flexor tendon of the great toe, compartment syndrome in the lower limb, valgus deformity of the ankle, or even a spontaneous fracture of the ipsilateral tibia (Shpitzer et al. 1997). We also saw donor-site complications in our series.

Many of our patients had had open fractures and osteomyelitis. Therefore, we preferred external fixation because of the lower risk of osseous tissue infection, in comparison to internal fixation. The drawback of pin-tract infection in an external fixator may be handled by pin-tract care or pin site change, which is much easier to deal with than osteomyelitis caused by use of an internal fixator such as a plate or nail. However, internal fixation is

more rigid than external fixation (Tu et al. 1995). In our series, internal and external fixations were often combined. The fractured vascularized bone graft could usually be treated well with plate osteosynthesis. Prevention of a graft fracture with early partial weight bearing and careful protection might accelerate bone hypertrophy and union. 3 fibula osteocutaneous flaps in our series were reoperated on due to venous thrombosis, and were salvaged with one more vein anastomoses. In view of the high reoperation rate with 1 vein anastomosis (3 in 5 patients), we propose that two vein anastomoses for fibula osteocutaneous transfer might be better than only one vein anastomosis.

- Bieber E J, Wood M B. Bone reconstruction. *Clin Plast Surg* 1986; 13 (4): 645-55.
- Buncke H J, Furnas D W, Gordon L, et al. Free osteocutaneous flap from a rib to the fibula. *Plast Reconstr Surg* 1977; 59 (6): 799-804.
- Carrington N C, Smith R M, Knight S L, et al. Ilizarov bone transport over a primary tibial nail and free flap: a new technique for treating Gustilo grade 3b fractures with large segmental defects. *Injury* 2000; 31: 112-5.
- Chacha P B. Vascularized pedicular bone grafts. *Int Orthop* 1984; 8 (2): 117-38.
- De Boer H H, Wood M B. Bone changes in the vascularised fibular graft. *J Bone Joint Surg (Br)* 1989; 71: 374-8.
- Fujimaki A, Suda H. Experimental study and clinical observations on hypertrophy of vascularized bone grafts. *Microsurgery* 1994; 15 (1): 726-32.
- Han C S, Wood M B, Bishop A T, et al. Vascularized bone transfer. *J Bone Joint Surg (Am)* 1992; 74: 1441-9.
- Hou S M, Liu T K. Reconstruction of skeletal defects in the femur with 'two strut' free vascularized fibula grafts. *J Trauma* 1992; 33: 840-5.
- Ikeda K, Tomita K, Hashimoto F, et al. Long-term follow-up of vascularized bone grafts for reconstruction of tibial nonunion, evaluation with computed tomography scanning. *J Trauma* 1992; 32: 693-7.
- Ilizarov G A. The tension-stress effect on the genesis and growth of tissue. 1. The influence of stability of fixation and soft tissue preservation. *Clin Orthop* 1989; 238: 249-81.
- Judet P B, Patel A. Muscle pedicle bone grafting of long bones by osteoperiosteal decortication. *Clin Orthop* 1972; 87: 74-80.
- Jupiter J B, Bour C J, May J W. The reconstruction of defects in the femoral shaft with vascularized transfers of fibula bones. *J Bone Joint Surg (Am)* 1987; 69: 365-74.
- Makley J T. The use of allografts to reconstruct intercalary defects of long bones. *Clin Orthop* 1985; 197: 58-75.
- Minami A, Kasashima T, Iwasaki N, et al. Vascularised fibular grafts. *J Bone Joint Surg (Br)* 2000; 8: 1022-5.
- Mizumoto S, Tamai S, Goshima J, et al. Experimental study of vascularized fibula grafts in inbred rats. *J Reconstr Microsurg* 1986; 3: 1-11.
- Paley D, Catagni M A, Argnani F, et al. Ilizarov treatment of tibial nonunions with bone loss. *Clin Orthop* 1989; 241: 146-65.
- Shpitzer T, Neligan P, Boyd B, et al. Leg morbidity and function following fibular free flap harvest. *Ann Plast Surg* 1997; 38: 460-4.
- Taylor G I, Miller G D, Ham F J. The free vascularized bone graft: A clinical extension of microvascular technique. *Plast Reconstr Surg* 1975; 55: 533-44.
- Tu Y K, Lin C H, Su J I, et al. Unreamed interlocking nail versus external fixator for open type III tibia fractures. *J Trauma* 1995; 39: 361-7.
- Ware J, Sherbourne C. The MOS 36-item short-form health survey (SF-36). I. Conceptual framework and item selection. *Medical Care* 1992; 30: 473-83.
- Wei F C, El-Gammal T A, Lin C H, et al. Free fibula osteocutaneous graft for reconstruction of segmental femoral shaft defects. *J Trauma* 1997; 4: 3784-92.
- Weiland A J. Current concepts review: Vascularized free bone transplants. *J Bone Joint Surg (Am)* 1981; 63: 166-9.
- Weiland A J, Moore J R, Daniel R K. Vascularized bone autografts: Experience with 41 cases. *Clin Orthop* 1983; 174: 87-95.
- Weiland A J, Phillips T W, Randolph M A. Bone grafts: A radiological, histologic, and biomechanical model comparing autografts, allografts, and free vascularized bone grafts. *Plast Reconstr Surg* 1984; 74: 368-79.