Free vascularised fibular grafting in the treatment of large skeletal defects due to osteomyelitis

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Abstract Treatment of skeletal defects secondary to osteomyelitis is a challenging problem. The purpose of this study was to present our experience of the use of free vascularised fibular grafts to treat such defects. Ten patients with a mean age of 31 years (range 16–50 years) and a skeletal defect with a mean length of 9.5 cm (range 6–17 cm) were managed with a protocol which included radical debridement of the lesion and a vascularised fibular graft. The mean follow-up time was 26 months. Union of the graft occurred in all patients, at a mean of 4.5 months. No recurrence of osteomyelitis was observed. The mean time to full weight bearing was ten months, and all patients were pain-free and able to walk without supportive devices. A free vascularised fibular graft is a viable option for the management of large skeletal defects resulting from osteomyelitis.

Introduction

Despite modern advances in antibiotics and surgical techniques, the long bone defect complicated by osteomyelitis usually presents a challenging problem for the treating surgeon [3].

Conventional autogenous bone-grafting is preferably used for defects of <6 cm, but it has limitations for the treatment of larger defects; the time-period for graft incorporation is prolonged, and the quantity of available autogenous graft is

limited. Moreover, in infected defects, scarring of the soft-tissue envelope compromises revascularisation of the graft [14].

Vascularised bone grafts, such as the vascularised fibular graft, retain their intrinsic blood supply, hasten bone-healing and hypertrophy [6], and have been widely used for reconstruction of large skeletal defects following trauma, tumour resection, or congenital diseases [5, 9–10, 15]. Bone defects of an infectious aetiology constitute a particularly challenging and important subgroup; however, only a few studies in the literature have focussed on the application of the free vascularised bone graft for the treatment of infected bone defects [4, 16, 18]. To investigate this question, we evaluated the use of a vascularised fibular graft to treat such a defect due to osteomyelitis.

Materials and methods

This study was reviewed and approved by our institutional review board, and informed consent was obtained from all patients. From January 2005 to June 2007, ten patients who had infected nonunion and bone defects were treated with the vascularised fibular graft at our institution. There were nine men and one woman whose average age was 31 years (range 16–50 years). All defects (including seven tibial defects and three femoral defects) were located in the lower extremity. The mean length of the skeletal defects was 9.5 cm (range 6–17 cm). The defect was the result of surgical debridement for the treatment of osteomyelitis in all patients. The osteomyelitis was post-traumatic in six patients and postoperative in four patients. *Staphylococcus aureus* was the most common organism, identified in seven of the ten cases.

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All patients were initially treated elsewhere and then referred to our institution. An average of 12 months (range 8–24 months) elapsed from the time of initial injury to presentation at our institution for treatment. During this interval, the patients had undergone three to seven operations, or an average of 3.9 operations each. On presentation, three patients had a limb-length discrepancy ranging from 1.5 to 4 cm (mean 2.6 cm). The median duration of infection was 6.5 months (range 3–12 months).

Management protocol

Before operation, we performed a careful preoperative preparation that included assessment of size of the bone defect, identification of the infecting organisms, and evaluation of the condition of both the adjacent soft tissue and the neighbouring joints. According to microbiological sensitivity tests, appropriate antibiotic was selected and used until there were no clinical signs of acute infection (erythema, swelling, or drainage) or laboratory signs of infection (an elevated erythrocyte sedimentation rate, C-reactive protein level, or leukocyte count). Once surgical treatment was decided upon, the patients were admitted to the osteomyelitis ward, where they were managed and reviewed prospectively.

In the operation, debridement and reconstruction with the vascularised bone graft were performed in one stage. First, a thorough debridement was done. All infected hardware was removed; an extensive resection of all avascular infected bone was performed back to bleeding tissue. Bone, soft tissue, and fluid samples were sent for aerobic, anaerobic, mycobacterial, and fungal cultures. The wound was copiously irrigated with physiological saline. Second, reconstruction of the defect with the vascularised fibular graft was carried out. Fibular dissection was done through a lateral approach under tourniquet control according to our previous technique [19]. It was important to leave at least 6 cm of the distal fibula to maintain ankle stability. The contralateral fibula was the donor bone in all cases. The mean graft length was 11.5 cm (range 6–20 cm). In the recipient site, the fibular graft was inserted into the medullary canal of the tibia or femur. Additional stability was provided by an external fixator or locking plate. Then, end-to-end or end-to-side arterial anastomosis was performed under an operating microscope. Finally, the wound was closed directly after insertion of drain tubes and covered with a dressing. After one week of postoperative intravenous antibiotics, the patients were discharged from the hospital.

The patients were followed up clinically and radiographically at regular intervals. The external skeletal fixator was removed when union was demonstrated roentgenographically. The involved extremity was braced, and weight

bearing was restricted not only until healing of the vascularised bone graft but also until hypertrophy of the graft had occurred.

The mean duration of follow-up was 26 months (range 14–40 months). The outcome variables for the purposes of this study included the union rate, the time to healing of the vascularised bone graft, the rate of limb salvage, and the infection rate. We also assessed the prevalence of complications, the time to full weight bearing, and the range of motion of the adjacent joints.

Results

The early postoperative course was uneventful; no patients experienced acute complications.

Bony union was achieved after our treatment in all patients. Primary union of the vascularised bone graft occurred in eight of the nine patients, at a mean of 4.5 months (range 3–8 months), as determined by evidence of bridging of three of the four cortices on plain radiographs. There was one nonunion of the distal graft–host junction site in a patient with a femoral defect. The nonunion was repaired with autogenous iliac crest bone grafting, and bony union was achieved three months later. There were no stress fractures seen.

No deep infection recurred. One superficial wound infection that responded well to limited debridement and antibiotic therapy was observed.

The mean time to full weight bearing following the reconstructions was ten months (range, 7–17 months) overall.

At the time of final follow-up, limb salvage and control of the infection had been achieved in all patients. All ten patients were able to fully bear weight on the lower extremity, and none was using any assistive device or brace. A limb-length discrepancy of ≤ 2 cm was present in one patients, who used a shoe raise.

At the time of the latest follow-up, no patient reported pain in the reconstructed extremity. Nine patients had a full range of motion of the adjacent joints. One patient had limitation of knee flexion (0–90°); however, the limitation had been present prior to the vascularised bone graft procedure.

Illustrative case reports

Case 1 The first case was a 37-year-old man with chronic infected nonunion after plate internal fixation for his left tibial shaft fracture. On referral, there was an open wound on his left leg through three debridement procedures performed at another hospital. After radical debridement,

we performed free vascularised fibular graft combined with locking compression plate (LCP) fixation. The postoperative course was uneventful, bone union was satisfactory in four months. Two years after operation, union remained sound and there had been no recurrence of the osteomyelitis (Fig. 1).

Case 2 The second case was a 41-year-old man who was in a car accident that caused left tibia and fibular fracture. The fractures were fixated with plates in the local hospital. The tibial fracture was infected and had nonunion nine months later. It was re-explored and transplanted with bone substitute. But the bone substitute was absorbed and a large bone defect occurred four months later. We did a free vascularised fibular graft combined with LCP fixation. In the operation, bone defect and sclerosis at the broken ends were observed. After removing the sclerotic bone from the broken ends, the bone defect was 6 cm (Fig. 2).

Discussion

Infected nonunion of a long bone remains a therapeutic challenge. The infection of the lesion site not only prevents stable internal fixation but also slows bone healing. Infection has been reported to be the main cause of delayed union or nonunion [1]. Thus, complete cure of the infection is the mainstay of treatment in such patients. As we know, the most effective cure for infection is radical debridement [2]. However, the extent of radical debridement necessary to obtain live and uninfected bone usually results in large bone defects, which require complex reconstruction [13]. Although this challenge can often be addressed by distraction osteogenesis, this treatment modality needs a prolonged consolidation period, causing great patient discomfort. Many patients and surgeons do not like this approach.

With the advent of microvascularised tissue transfer, extensive bone defects resulting from radical debridement

Fig. 1 **a** Roentgenograms on referral. **b** Roentgenograms after our debridement showed a 9-cm tibial defect. A microvascular fibular transfer with locking compression plate (LCP) was performed to reconstruct the tibial bone defect. **c** Roentgenograms after 4 months showed good union of the grafted fibular bone. **d** Roentgenograms after 2 years showed good hypertrophy of the grafted fibular bone

can be repaired by this method [7]. The main purpose of this article is to present our experience of the use of free vascularised fibular grafting in the treatment of segmental defects resulting from debridement of osteomyelitis.

In this study, we used a one-stage treatment protocol. The goal of infection elimination was achieved via radical debridement until live and bleeding bone was reached. The bone and soft tissue reconstruction was performed in one stage until we were confident that infection could be controlled and extensive soft and bone defects could be repaired by free vascularised fibular grafting. This treatment protocol provided rapid recovery from osteomyelitis and predictable recovery from nonunions. During the course of treatment, the wound care was simple and comfortable, with no need for a prolonged period of treatment with systemic antibiotics.

From our experience, we found that application of rigid fixation, the technique of free vascularised fibular transfer and antibiotic treatment were very helpful in the treatment of infected bone defects. The bone healing occurs if bacterial activity is contained, the vascular environment at the lesion site is ensured, and stable fixation and soft tissue coverage are provided with early and adequate bone grafting. This can all be achieved by adequate debridement and stabilisation of the lesion and reconstruction of the bone defect.

Debridement

Thorough and adequate debridement is the most important principle in eradicating osteomyelitis. The sinus tract, infected soft tissue, and unhealthy granulation tissue must be excised and subjected to microbiological and histological examination. Loose and sequestered bone should be removed. Excision of bone is guided by the punctate bleeding test [11].

Stable fixation

Generally, stability of the lesion site was achieved with an external fixator. Stabilisation of the lesion by external fixator decreases interfragmentary motion, reduces inflammation, and provides an improved milieu for graft incorporation and bone union. But the external fixator was inconvenient for daily life of patients and runs the risk of pin tract infection. Thus, in this study, in nondraining and inactive infections, locking plate fixation could also be done when radical debridement had been performed. Locking plate is like an internal fixator system which combines both the advantages of external fixation techniques and the early advances of the so-called biological plating technique into one system. In our practice, this approach not only brings convenience to patients, but also

achieves a good result in treating infected nonunion of the long bone (Figs. 1 and 2). But at the same time, this technique may enhance the risk of infection, especially in active infection.

Reconstruction of bone defects by free vascularised fibular graft

In the past, some authors thought that the free vascularised fibular graft could only be done at specialised centres and was time consuming. These grafts took years to hypertrophy and often fractured one or more times before remodelling was complete. The grafts often failed to unite to the recipient osseous tissue at one or both ends. The incorporation of microvascular osseous transplant in host bed is 40% in patients with osseous sepsis [8].

However, in our study, fatigue fracture and nonunion of the vascularised fibular grafts have seldom been encountered, and there has been no donor site morbidity in any patient. We modified the surgical technique of harvesting the fibula. The operating time necessary to transfer a viable bone graft, as compared with a conventional graft, is not excessive. The time to harvest the fibula and to close the donor wound has averaged 0.5–1.0 hours, and the time spent microscopically anastomosing blood vessels is usually less than one hour.

The free vascularised bone graft offers some particular advantages for the reconstruction of major skeletal defects. It has unique anatomical and biological properties [5, 9–10, 15]. The size and straight configuration of the fibular graft allow it to fit into the medullary canal of the femur or tibia, facilitating reconstruction of extensive defects up to 26 cm [1, 12]. The fibula has dual vascularity, derived from endosteal and periosteal vessels, which is retained when successful microvascular anastomoses are performed between the graft pedicle and the recipient-site vessels [17]. As a result, the vascularised bone graft bypasses the process of creeping substitution, which characterises healing of avascular grafts, and involves graft necrosis, resorption, and new bone formation. The vascularised bone graft maintains its mass and architecture to a greater degree, is biomechanically stronger than an avascular fibular graft, and demonstrates enhanced healing potential and hypertrophy [3]. In addition, the vascularised bone graft provides an important source of vascularity in scarred and avascular recipient sites. Thus, for some infected defects of <4 cm with poor soft tissue and blood supply, vascularised fibular graft can be used (as shown in Fig. 2).

Antibiotics

The appropriate antibiotics should be chosen after isolation, identification, and antibiotic susceptibility testing of the

Fig. 2 **a** Roentgenograms before surgery. **b** Roentgenograms after first internal fixation. **c** Roentgenograms after 10 months showed nonunion. Debridement and artificial bone graft were performed. **d** After 4 months roentgenograms showed that artificial bones were absorbed. **e** Anteroposterior and lateral radiographs postoperatively showing free vascularised fibular grafts combined with locking compression plate (LCP). **f** Anteroposterior and lateral radiographs at 7 months showing the solid union of the graft

infectious agent. An antibiotic specific for staphylococcus (nafcillin, fusidic acid, cloxacillin, vancomycin, teicoplanin) should be started while waiting for the results of the culture report. The duration that antibiotics are given depends on the duration of infection, infective organism, adequacy of surgical treatment, host resistance, and

antibiotic properties. Six weeks of antibiotic therapy is advocated largely by experience with childhood chronic haematogenous osteomyelitis. It may not be applicable in treating continuous focus osteomyelitis after trauma in adults. The treatment should be monitored for potential adverse effects. The surgical debridement converts

an infection with dead bone to a vascularised tissue that is penetrated better by systemic antibiotics.

In this series, by using the free vascularised fibular graft, we have successfully reconstructed ten infected defects (6–17 cm). The osseous unions occurred within 4.5 months, and all of the grafted fibular bones eventually obtained good union. The donor site morbidity was negligible. After 14–40 months of follow-up, we conclude that this treatment protocol provides rapid recovery from osteomyelitis and that free vascularised fibular transfer is a good method for the management of infected long-bone defects.

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