VASCULARISED FIBULAR GRAFTS FOR RECONSTRUCTION OF THE FEMUR

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From 1979 to 1990 we treated 20 patients with large bone defects or established nonunion of the femur by vascularised fibular grafts. There were 18 men and two women with an average age at operation of 36.6 years (16 to 69). Ten patients had infected nonunion, three had post-traumatic nonunion or a bone defect without infection, four had a defect after tumour resection, and three had other lesions. The mean length of the fibular grafts was 18.1 cm.

Postoperative circulatory disturbances needed revision surgery in five patients, including three with circulatory problems in the monitoring flap, but not at their anastomoses. The outcome was successful in 19 of the 20 patients with bone union at means of 6.1 months at the proximal site and 6.6 months at the distal site. Three patients had fractures of the fibular grafts but all these united in two to three months after cast immobilisation.

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Extensive defects in long bones have been reconstructed by autogenous or homologous bone grafting, but this requires a prolonged time for bone union, and sometimes fails. Even after bone union, there may be atrophy of the grafted bone, leading to fracture. The introduction of vascularised bone grafts, preserving blood flow in the donor bone, has improved results for nonunion associated with bone deficiency. The fibula is frequently used to provide the graft (Taylor, Miller and Ham 1975; Tamai et al 1980).

Since 1976, we have performed vascularised fibular grafting (VFG) in 110 patients with some excellent results, using a microsurgical technique which takes more time than most orthopaedic operations. Even more time is required for VFG when the condition of the vessels is poor, as in cases of chronic inflammation. VFG to the femur is further complicated because the host bone is located deeper than other long bones and has only one major artery. In addition, very heavy loads may be applied to the grafted bone, requiring careful and sometimes prolonged postoperative management. Despite these problems, the demand for femoral VFG has been increasing; notably after resection of malignant bone tumours, for the salvage of infected artificial joints, and for intractable infected nonunion.

PATIENTS AND METHODS

Twenty patients had undergone femoral VFG with a follow-up of at least 18 months. There were 18 men and two women; their ages at operation ranged from 16 to 69 years (mean 36.6). The indication was infected nonunion or bone deficit in ten, bone tumour in four, nonunion or bone deficit without infection in three, chronic osteomyelitis in one, infected femoral component of a total hip replacement in one, and malunion after epiphyseal injury in one. The femoral head and neck were involved in one patient, the proximal diaphysis in three, the mid-shaft in seven, and the distal diaphysis or supracondylar region in nine. Most patients had undergone several operations: in those with trauma this ranged from three to six (mean 4.6). Fifteen patients had segmental bone defects, ranging from 2 to 17 cm (mean 8.2). The donor fibula varied in length from 10 to 26 cm (mean 18.1). Double vascularised...
grafting was performed in one patient, and seven had twin-barreled fibular grafting on a single vascular pedicle. In these cases, counting each half as one graft, the length of grafted fibula ranged from 10 to 23 cm (mean 13.4).

In five patients, the donor fibula was from the ipsilateral leg, and in two of these it was transplanted as an island flap. In the patients having free grafts, the peroneal artery was anastomosed according to the level of the graft: 1) for the proximal femur by end-to-end anastomosis to the lateral femoral circumflex artery; 2) for the middle of the femur by either end-to-end anastomosis to the deep femoral artery, end-to-side to the femoral artery, or via a vein graft to the lateral femoral circumflex artery; and 3) for the distal femur by end-to-side anastomosis to the femoral artery or end-to-end to the genicular artery or sural artery. In most cases, the venae comitantes of the peroneal artery were anastomosed to the long saphenous vein. In half the cases, anastomosis to both venae comitantes was performed.

The fibular graft was immobilised by external skeletal fixation in 11 patients, by plate fixation in three, and by intramedullary fixation in one. In the remaining five, the fibula was fixed with screws and a spica cast was used. The duration of external skeletal fixation averaged 6.3 months (4 to 11). In nine cases (45%), fibular grafting was complemented by iliac bone grafts.

The duration of the operation ranged from six hours to 11 hours 20 minutes (mean 8 hours 5 minutes). Blood loss was from 750 ml to 4375 ml (mean 1982). Follow-up was from 18 months to 11 years 4 months (mean 4 years 4 months).

RESULTS

In 14 patients skin flaps were taken with the fibular graft, including flaps used only for monitoring the circulation, and in another two the peroneus brevis muscle was used as a monitoring flap (see Figs 4, 5). In one of these 16 patients, the flap was removed after the fibular graft had been placed because it did not reach the surface, and in five of the remaining 15 patients, the flap showed colour changes after operation, necessitating re-exploration (Table I). In one of these there had been a venous thrombosis and in one an arterial thrombosis; both had a thrombectomy, and one had vein grafting. Both of these flaps took successfully. In the other three patients, the changes in the monitoring flap were attributed to disturbed circulation in the flap itself due to stretching of the perforating vessels by swelling. In two of these the flap position was changed, and in the third the flap was removed. In four patients no flap was used. One developed an infection, and re-exploration showed vascular obstruction.

In total, grafting was successful in 19 of the 20 patients (95%). The time required for satisfactory bone union after grafting in these 19 patients was three to 18 months (mean 6.1) for the proximal junction and three to 18 months (mean 6.6) for the distal one. The cause of delay in the case which required 18 months was recurrence of osteomyelitis necessitating an additional bone graft. Excluding this case, the mean time to union was 5.4 months proximally and 5.9 months distally. Grafting after resection of bone tumours produced earlier union (3.8 months proximally, 4.8 months distally). The time until the patient could walk without braces ranged from four months to two years (mean 12.2 months), a much shorter time than that reported after conventional bone grafting.

There was a fracture of the grafted fibula in three cases, but they all united after cast fixation for two months, showing a marked increase in the transverse diameter of the grafted bone. In one case, a fracture of the unreseected femoral cortex required replacement of the cast with an external skeletal fixation device. There was some localised infection in two cases; one was due to recurring osteomyelitis after the vascular failure of a fibular graft, and the other healed slowly after curettage and iliac bone grafting. There was local recurrence of a giant-cell tumour in one case, necessitating amputation through the femur. Additional bone grafting was performed in three patients, including two with recurrent osteomyelitis.

Table I. Details of the five cases of infected nonunion in which re-exploration of the graft and monitoring flap was required

<table>
<thead>
<tr>
<th>Age</th>
<th>Sex</th>
<th>Problem</th>
<th>Procedure</th>
<th>Monitoring flap</th>
</tr>
</thead>
<tbody>
<tr>
<td>33</td>
<td>M</td>
<td>Venous thrombosis</td>
<td>Vein graft</td>
<td>Survival</td>
</tr>
<tr>
<td>38</td>
<td>M</td>
<td>Stretched perforating vessels</td>
<td>Resection of flap</td>
<td>-</td>
</tr>
<tr>
<td>32</td>
<td>M</td>
<td>Arterial thrombosis</td>
<td>Thrombectomy</td>
<td>Survival</td>
</tr>
<tr>
<td>18</td>
<td>M</td>
<td>Stretched perforating vessels</td>
<td>Transfer of flap</td>
<td>Survival</td>
</tr>
<tr>
<td>53</td>
<td>F</td>
<td>Stretched perforating vessels</td>
<td>Transfer of flap</td>
<td>Survival</td>
</tr>
</tbody>
</table>

*the fibular graft was successful with union at six months

Illustrative case reports

Case 1. A 23-year-old man developed osteomyelitis after open reduction and nail fixation of a femoral shaft fracture at an emergency hospital. Infection continued after debridement and replacement of the nail with an external fixation device. At our clinic, two attempts at debridement and closed irrigation also failed to control it (Fig. 1a). When the ESR and C-reactive protein levels had improved we performed free vascularised fibular grafting with additional iliac crest grafts, using internal fixation with an AO plate (Fig. 1b). Walking in an ischial-bearing brace was allowed from two months. Union was achieved with mild residual varus deformity due to loosening of the plate. At five-year follow-up the
Case 1. Figure 1a - The left femur with external fixation after radical debridement for osteomyelitis. Figure 1b - After an onlay vascularised fibular graft and an inlay iliac bone graft with AO plate fixation. Figure 1c - At five years and two months there is solid union but some residual bowing.

Case 2. Figure 2a - Pre-operative radiograph showing a chondrosarcoma of the right femur. Figure 2b - A vascularised fibular graft was used with the remaining lateral cortex of the femur to secure an arthrodesis of the knee. This was immobilised with an external fixator. Figure 2c - At three years there is sound union and no recurrence of the tumour.
Case 3. Figure 3a - Infected nonunion of the right femur with a Kuntscher nail in position. Figures 3b and 3c - Anteroposterior and lateral radiographs one month postoperatively showing double vascularised fibular grafts. Figures 3d and 3e - Anteroposterior and lateral radiographs at two years showing the increase in thickness of the inlay fibular graft. Figure 3f - CT scan at one year eight months showing considerable hypertrophy of the inlay graft.
range of knee flexion was 0° to 110°, and the patient had returned to his original employment (Fig. 1c).

**Case 2.** A 44-year-old man with a chondrosarcoma of the right distal femur (Fig. 2a) was treated by extensive excision and knee arthrodesis using a 20 cm fibular graft from the contralateral side. The distal end of the graft was inserted into the marrow of the tibia, and the proximal end was fixed end-to-side to the femoral shaft. The peroneal artery was anastomosed to the sural artery, and both veins were also anastomosed.

After operation, cast immobilisation was used, but one month later a fracture of the unresected femur required the use of an external fixator (Fig. 2b). Bone union was satisfactory in four months. Three years after operation union remained sound and there had been no recurrence of the tumour (Fig. 2c).

**Case 3.** A 36-year-old man had infected nonunion of the right femur after a shaft fracture which had been treated elsewhere by internal fixation and then by intramedullary nailing for breakage of the plate (Fig. 3a). There was nonunion and osteomyelitis which was treated twice by curettage and then by filling the defect with antibiotic-loaded bone cement.

The patient was referred to us with a dry wound for reconstruction of a 7 cm bone defect. Fibular grafting was performed from the ipsilateral side, cutting the 25 cm fibular section to serve as a twin-barrelled vascularised graft. One half was fixed within the marrow and the other was screwed to the side of the femur as an onlay graft; immobilisation was provided by an external fixator (Figs 3b, c). The peroneal artery was anastomosed to the lateral femoral circumflex artery and its venae comitantes were anastomosed to those of the circumflex artery and to the saphenous vein. The postoperative course was good, with bone union in five months, and removal of the external fixator at six months.

The fibular graft fractured twice, at nine months and at one year, but a cast support resulted in bone union on both occasions. Two years postoperatively, the diameter of the grafted fibula had increased over that of the original femur (Figs 3d, e, f), and the patient had returned to work as a carpenter.

**DISCUSSION**

Nonunion of the femur with a large bone deficit is very difficult to treat especially when it is complicated by infection. Toriyama et al (1977) reported a mean of two years five months before union in 12 patients with infected femoral nonunion and an average bone deficit of 5.2 cm. Vascularised bone grafting should provide surer and more rapid bone union, and in our series and in others, this has been achieved in four to six months (Okubo et al 1985; Jupiter, Bour and May 1987). Unlike other bone grafts, there is no postoperative bone atrophy, and hypertrophy is usually seen. In experiments on the rat tibia and fibula we have demonstrated that this is related to loading of the graft and to the environment at the recipient site (Mizumoto et al 1986). Similar findings have been reported in clinical cases, and we have found that hypertrophy of the transverse diameter of the grafted fibula was more marked after inlay than after onlay grafting. This was seen clearly after our recent use of twin-barrelled grafting which produces considerable hypertrophy of the fibular graft transplanted into the marrow. This type of hypertrophy appeared early after the fractures in case 3 (Fig. 3).

**Fig. 4**

Twin-barrelled vascularised fibular grafts with attached peroneus brevis muscle and a monitoring skin flap. The perforating vessels (P), leading to the skin flap, are short, but the muscle flap (M) can be taken at any length.

**Fig. 5**

The use of a peroneus brevis muscle flap to monitor the circulation in a fibular graft. The tip of the monitoring muscle is placed in the skin suture line.

Vascularised fibular grafting also has some disadvantages. It requires special microsurgical techniques and more operative time. For the femur there are more technical difficulties, because this bone has few main vessels suitable for anastomosis to the graft. In the proximal third of the femur, the deep femoral artery and the lateral femoral circumflex artery can be used relatively easily, but in the mid-shaft only the main trunk of the
femoral artery can be used, either by end-to-side or by end-to-end anastomosis using vein grafting. Recently, we have more often used the latter method, anastomosing the vein grafts to the peroneal artery and the venae comitantes before the fibula is fixed to the femur. After this a superficial vessel, usually the lateral femoral circumflex artery, can be used for anastomosis. This simplifies the operation and reduces the operating time; the latter can be further shortened by using the contralateral fibula so that its collection can be performed by one team while the recipient site is prepared by a second team.

Another difficulty in applying this grafting technique to the femur is that the bone is difficult to hold in good alignment. We recommend the use of an external fixator, and, in recent years, have found the Orthofix device (Orthofix; Bussolengo VR, Italy) to be best in terms of simplicity of manipulation and strength. In addition, it allows telescoping after early bone union has taken place, providing a longitudinal stress on the femur as a stimulus to increase the diameter of the grafted bone. It may be that careful use of this method could intentionally induce a stress fracture, and thereafter more rapid enlargement of the graft (Yajima and Tamai 1991).

Another problem is the weakness of the grafted fibula. Even when its diameter has increased after union, a single fibular graft is unlikely to withstand the full loading of activity. The most usual answer is to use supplementary conventional iliac bone grafts, and we have used these in nine cases. When the femoral defect is more extensive, a dual fibular graft is required, although this further increases the duration of the operation (Okubo et al 1985). If the defect is shorter than 13 cm, however, the technique of twin-barrelled fibular grafting, carried out by dividing the graft into two segments while preserving the periosteum and peroneal vascular supply, can be very useful. This method was first reported by Jupiter et al (1987) and later by Jones et al (1988) and Toh et al (1988).

The final problem in vascularised fibular grafting of the femur is postoperative monitoring. The usual technique is the use of a monitoring flap of skin, but this has not been possible in some of our patients. In one, the flap did not reach the surface of the thigh, and in three others, postoperative swelling stretched the perforating vessels and disturbed the circulation to the monitoring flap, but not to the bone. Similar cases have been reported by Jupiter et al (1987). The length of the perforating vessels can be maximised by taking the monitoring flap from the centre or proximal third of the leg, but the proximal perforating vessels frequently originate from the posterior tibial artery and cannot be used (Chen et al 1985). We have devised a new method in which the peroneus longus or brevis muscle is used to monitor circulation. The muscle is left attached to the fibula (Fig. 4) with its tip exposed in the wound to provide its monitoring function (Fig. 5). This method has been effective in two cases in our series.

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REFERENCES


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