The results and complications of 104 vascularised fibular grafts in 102 patients are presented. Bony union was ultimately achieved in 97 patients, with primary union in 84 (84%). The mean time to union was 15.5 weeks (8 to 40). In 13 patients, primary union was achieved at one end of the fibula and secondary union at the other end. In these patients, the mean time to union was 31.1 weeks (24 to 40). Five patients failed to achieve union, with a resultant pseudarthrosis (3 patients) or amputation (2 patients).

There were various complications. Immediate thrombosis occurred in 14 cases. In two of 23 patients with osteomyelitis, infection recurred at two and six months after surgery, respectively. Both patients had active osteomyelitis less than one month before the operation. Bony infection occurred in a patient with a synovial sarcoma of the forearm one year after surgery. In 15 patients, 19 fractures of the fibular graft occurred after bony union, all except one within one year after union. In patients in whom an external fixator had been used, fracture occurred soon after its removal. Union was difficult to achieve in cases of congenital pseudarthrosis of the tibia. Appropriate alignment of the fibular graft is an important factor in preventing stress fracture. The vascularised fibula should be protected during the first year after union.

Postoperative complications at the donor site included transient palsy of the superficial peroneal nerve in three patients, contracture of flexor hallucis longus in two and valgus deformity of the ankle in three.

Vascularised fibular grafts are useful in the reconstruction of massive bony defects. We believe that meticulous preoperative planning, including choosing which vessels to select in the recipient and the type of fixation devices to use, and care in the introduction of the vascularised fibula, can improve the results and prevent complications.

Received 30 June 1999; Accepted after revision 6 April 2000

The use of vascular fibular grafts has been described for the treatment of segmental bony defects, osteomyelitis, bone loss after resection of tumours, kyphosis and congenital pseudarthrosis of the tibia. The procedure, however, is technically demanding and has a significant rate of complications.

We have carried out 104 vascular fibular grafts in 102 patients with a follow-up of at least two years. Our aim was to evaluate the outcome, as defined by bony union, report the complications and identify factors which affect the results.

Patients and Methods

Between 1976 and 1995 we carried out 136 vascularised fibular grafts in 134 patients. In 18 patients thrombosis of the fibular blood supply occurred either during or after operation and they were excluded. Another 12 patients were excluded because of insufficient follow-up, and two died from unrelated causes. This left 102 patients (104 grafts) for review. There were 68 men and 34 women with a mean age of 35.6 years (1 to 73). The mean time to follow-up was 7.5 years (2 to 21.7).

The indication for surgery was a bony defect or pseudarthrosis caused by trauma in 33 patients, excision of a tumour in 26, osteomyelitis with a bony defect in 23, kyphoscoliosis in 13 and congenital pseudarthrosis of the tibia in seven.

The recipient sites for the grafts included the tibia in 37 patients, the femur in 25, the radius and ulna in 14, the spine in 13, the humerus in ten and the ilium in three.

There were 97 free and seven pedicle vascularised fibular grafts. In two patients, free and pedicle vascularised grafting was carried out simultaneously. The method of harvesting the fibula has been previously described.

Recently, we have used a vascularised osteocutaneous fibu-
lar graft in most patients in order to cover an associated skin defect and/or to monitor the perfusion of the graft. There have been 50 such composite grafts and 54 routine vascularised fibular grafts. The mean size of the cutaneous flap was 3 ± 8 cm. The mean length of graft was 14.3 cm (5 to 28). The fibula was folded into two or three segments in 15 cases.

The graft was stabilised by an external fixator in 51 patients, a plate in 24, screws in seven (including four ISOLA pedicular screws), and an intramedullary nail in six. In the remaining 14 patients, no fixation devices were used. ISOLA pedicular screws were used to reconstruct the pelvic ring in three patients and for arthrodesis of the hip in one.

In 80 of the 102 patients, a supplementary iliac bone graft was also used. Of the 22 patients who did not require added bone graft there were 13 with kyphoscoliosis, seven with congenital pseudarthrosis of the tibia, one with a traumatic bony defect and a child with a bony defect secondary to osteomyelitis.

Postoperatively, we initially used routine anticoagulant therapy, but have recently abandoned this practice.

Postoperative perfusion of the grafted fibula was assessed by direct observation of the cutaneous flap, Doppler flowmetry and/or 99mTc methylene diphosphonate bone scintigraphy.

Anteroposterior (AP), lateral, and oblique radiographs were obtained at two-weekly intervals after surgery. Bony union was determined by the presence of bridging bony trabeculae on at least one radiograph. Tomograms were taken if union was uncertain on plain radiography. Union was routinely evaluated 24 weeks after surgery. If union had not been achieved, a further bone graft was carried out in all patients except one. If abnormal mobility was noted at the junction between the recipient and the grafted fibula before 24 weeks after operation, a further bone graft was undertaken.

The results were classified as good, fair or poor. A good result had primary union at both ends of the graft without further surgery. A fair result required a secondary procedure or additional bone grafts, either conventional or vascularised, at one end of the graft. A poor result represented persistent nonunion.

Statistical comparisons of the data were made using chi-squared and Student *t*-tests. A *p* value of less than 0.05 was considered to be statistically significant.

### Results

The results were good in 84 patients (82%), fair in 13 (13%) and poor in five (5%).

Bony union was achieved in 97 patients (95%), in 84 at a mean postoperative time of 15.5 weeks (8 to 40). One patient refused a further procedure 24 weeks after surgery, but union occurred after immobilisation in a cast for another 16 weeks. In the 13 patients with a fair result union was achieved at a mean postoperative time of 31.1 weeks (24 to 40), and in the five patients with a poor result there was no union.

The factors affecting bony union were evaluated. Table I shows the relationship between the pathogenesis and union. The patients with congenital pseudarthrosis of the tibia had significantly poorer results.

The effect of added bone graft on the rate of union was assessed. In 80 patients who had a conventional bone graft, 66 (83%) obtained primary union while in 22 patients without a conventional bone graft 18 (82%) had primary union. A statistical comparison between the two groups could not be undertaken as patients without added bone grafts were in the kyphoscoliosis group and the follow-up was for less than ten years.

In the 50 cases in which a cutaneous flap has been used, postoperative perfusion of the grafted fibula was assessed by observation of the colour of the flap, and in the 54 without a flap by laser Doppler flowmetry and/or a bone scan.

There were no significant intraoperative complications. There were 14 cases of early postoperative thrombosis of which 12 were venous and two arterial. All were recognised on the first day after operation and were immediately explored. Blood flow was successfully restored by thrombectomy and vein grafting in all cases.

Delayed postoperative complications included nonunion, the recurrence or development of osteomyelitis, failure of fixation, fibular fracture, cutaneous flap necrosis, sensory disturbances, contracture of flexor hallucis longus and valgus deformity of the donor ankle.

Five patients developed nonunion. In one, a congenital pseudarthrosis of the tibia failed to unite despite two secondary grafting procedures. An above-knee amputation was performed three years after the primary operation. One arthrodesis failed in a patient with a neuropathic elbow, with a resultant pseudarthrosis. One patient, with a synovial sarcoma of the forearm, developed osteomyelitis after vascularised fibular grafting had been carried out with a wide local resection of the tumour. The infection led to a pseudarthrosis.

The infection recurred in two of 23 patients with osteo-

### Table I. The relationship between the pathogenesis and bony union for the 102 patients treated with vascularised fibular grafts

<table>
<thead>
<tr>
<th>Pathogenesis</th>
<th>Number of cases</th>
<th>Bony union</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Good*</td>
</tr>
<tr>
<td>Bony defect or pseudarthrosis after trauma</td>
<td>33</td>
<td>26</td>
</tr>
<tr>
<td>Bony defect after removal of bone and soft-tissue tumours</td>
<td>26</td>
<td>24</td>
</tr>
<tr>
<td>Osteomyelitis with bone defect</td>
<td>23</td>
<td>20</td>
</tr>
<tr>
<td>Spinal kyphoscoliosis</td>
<td>13</td>
<td>13</td>
</tr>
<tr>
<td>Congenital pseudarthrosis of the tibia</td>
<td>7</td>
<td>1</td>
</tr>
</tbody>
</table>

* *p* < 0.05, congenital pseudarthrosis of the tibia vs all other pathogeneses
myelitis and a bony defect (9%) in the radius and tibia respectively, at two and six months and resulted in persistent pseudarthrosis and an above-knee amputation, respectively. The osteomyelitis was deemed quiescent when the white cell count was normal (less than 8000/mm$^3$), the ESR was less than 15 mm/hour, the level of C-reactive protein was normal and bacterial cultures, from any exudate, were negative. If one of these criteria was not satisfied, the infection was considered to be active. We divided the patients into two groups according to the length of the prepertoperative quiescent period; less than one month (4 patients) and more than one month (19 patients). Both patients with recurrent osteomyelitis belonged to the first group. The incidence of recurrent infection was significantly less in those patients whose infection had been quiescent for more than one month before operation ($p < 0.05$).

Stress fractures of the grafted fibula occurred in 15 patients (15%); four had two fractures each, giving a total of 19. In only one patient was there a history of trauma. The other patients noticed local pain or swelling without specific injury.

There were four (12%) fractures in the 33 patients with traumatic bony defects, two (8%) in the 26 patients with tumour, three (13%) in the 23 with osteomyelitis, none in the 13 with kyphoscoliosis, and six (86%) in the seven with congenital pseudarthrosis of the tibia.

Rates of fractures for the different recipient sites were 12 (32%) of 37 in the tibia, one (10%) of ten in the humerus, two (8%) of 25 in the femur, none of 14 in the radius and ulna, none of 13 in the spine and none of three in the ilium.

The mean interval between bony union and fracture was 3.5 months (0.5 to 16). Most patients were wearing external supports when the fractures occurred: a patellar tendon-bearing orthosis in 11, a long-leg cast in four, and a knee-ankle-foot orthosis with an ischial seat in two. Two patients had no support. The fractures occurred during full weight-bearing in two patients, partial weight-bearing in 15 and when non-weight-bearing in two.

All fractures were initially treated by immobilisation in a cast and ten of the 19 healed by immobilisation alone. The time required for union ranged from two to five months. Nine required additional procedures. Three were treated by a conventional graft from the iliac crest, and one by partial resection of the fibula because of compression at the site of the fracture. Five cases of congenital pseudarthrosis of the tibia required either a second vascularised bone graft (3 fractures) or bone transport (2). The mean time to union in these cases was 22 months (8 to 35).

Statistical comparisons of predictable factors were undertaken between grafts to the tibia with fracture and those without fracture using the unpaired Student $t$-test and Fisher’s exact test. Cases of congenital pseudarthrosis were excluded from this comparison. There were six patients with seven fractures (mean age 41 years) and 24 without (mean age 56 years). The length and the alignment of the graft, as measured on the AP and lateral radiographs, were compared in the two groups. Malalignment was defined as an angle between the two axes greater than 10°. The lengths of the graft were 19.5 ± 4.8 cm (12 to 25) in the patients with fracture and 11.6 ± 4.9 cm (7 to 22) in those without. Longer grafts were associated with significantly higher rates of fracture ($p < 0.002$). Six of 16 (38%) malaligned grafts fractured. There were no failures in the grafts which were properly aligned ($p < 0.02$).

All donor sites were closed primarily; the wounds did not heal in two patients who required a skin graft. A transient superficial palsy of the peroneal nerve occurred in five cases. Postoperative contracture of flexor hallucis longus occurred in two patients, and a release was carried out in one. Valgus deformity of the ankle occurred in three patients, all aged less than ten years, and two had a congenital pseudarthrosis of the tibia. There were no cases of postoperative valgus deformity of the ankle in adults.

**Discussion**

There have been many reviews of the use of vascularised fibular grafts$^{1-4,6-17}$ and most have reported good results. Although in our series there was bony union in 97 of 102 patients, there was also a significant rate of complications.

Han et al$^7$ described the results of reconstruction of a skeletal defect with a vascularised bone graft from the iliac crest or fibula in 160 patients. The results were less satisfactory for patients who had had the reconstruction for bone loss due to osteomyelitis. In our series, however, 20 of 23 patients with osteomyelitis obtained primary union with infection recurring postoperatively in two patients. There was active infection less than one month before surgery in both cases. Vascularised fibular grafts should be delayed for at least one month after markers of active inflammation have become normal.

Fracture of the graft was the most common late postoperative complication. Previous authors have found the incidence of fracture to be 20% to 40%.$^{17,18}$ In our series, fractures occurred in 15%. Satisfactory alignment of the grafted fibula would seem to be an important factor in preventing fracture after union has occurred.

Hou and Liu$^1$ noted that two fibular grafts provided sufficient mechanical strength for reconstruction of the femur, with no subsequent refracture. We also had no refracture in patients treated with fibulae folded two or three times. A defect of less than 12 to 13 cm can be reconstructed using a single vascular pedicle as described by Jupiter et al$^2$ and Toh et al.$^5$

Fracture of the graft occurred in six of seven patients with congenital pseudarthrosis of the tibia. It is difficult to achieve union in this condition.$^{13}$ Tarnai$^{14}$ reported that fractures of the graft after treatment for congenital pseudarthrosis by vascularised fibular grafts resulted in delayed...
union and pseudarthrosis in ten of 21 cases (48%), and additional grafting was required to obtain bony union. Weiland et al.\textsuperscript{15} found that 14 of 19 patients (74%) obtained primary union at both ends of the graft within three to six months. There were five patients (26%) with nonunion. A factor in the high incidence of fracture may be the necessity of using grafts which are longer than the pseudarthrosis in order to restore the length of the limb. Increased tension in the musculature of the calf may result in bowing of the tibia and the fibular graft anteriorly. We found that most of these patients also developed an equinus deformity of the ankle, caused by increased muscle tension. Adequate immobilisation is difficult in these young patients. We currently advise a well-fitted, long-leg cast with the knee in slight flexion. Weight-bearing should be avoided for at least six months after union of the graft and a protective orthosis should be worn for at least two years.

All but one refracture occurred within one year of operation. De Boer and Wood\textsuperscript{17} have stated that a vascularised graft should be protected during the first year, but loading should gradually increase to enhance remodelling and hypertrophy of the graft. We advocate the use of external fixator frames which can be adjusted to allow load-sharing. Mechanical alignment of the fibular graft also has an important role in preventing stress fracture.

Several postoperative complications at the donor site have been reported.\textsuperscript{19} Tight suturing of flexor hallucis longus to peroneus longus and brevis, and tight skin closure may cause a contracture of flexor hallucis longus, as occurred in two of our patients.

Valgus deformity of the ankle is a frequent complication in children, and occurred in three of our patients. In most cases at least the distal one-quarter of the length of the fibula, approximately 8 or 9 cm in adults, remained intact. When the distal part of the fibula is required, the distal tibiofibular joint should be stabilised by screw fixation just proximal to the joint. We encountered no cases of postoperative deformity of the ankle when this was done, and these patients were less than ten years old at the time of operation.

Vascularised fibular grafting is a useful procedure for the reconstruction of massive bony defects. Postoperative complications can be minimised by meticulous planning of the procedure. Important considerations include the choice of vessels in the recipient, the method of anastomosis (antegrade or retrograde, end-to-end or end-to-side), the use of a vein graft, the type of fixation device and the introduction of the graft without angulation.

We thank Dr A. T. Bishop, MD, Department of Orthopaedics, Mayo Clinic, Rochester, USA for his constant interest and guidance in this investigation.

No benefits in any form have been received or will be received from a commercial party related directly or indirectly to the subject of this article.

References