Reconstruction with non-vascularised fibular grafts after resection of bone tumours

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We evaluated 31 patients who were treated with a non-vascularised fibular graft after resection of primary musculoskeletal tumours, with a median follow-up of 5.6 years (3 to 26.7 years). Primary union was achieved in 89% (41 of 46) of the grafts in a median period of 24 weeks. All 25 grafts in 18 patients without additional chemotherapy and/or radiotherapy achieved primary union, compared with 16 of the 21 grafts (76%; 13 patients) with additional therapy (p = 0.017). Radiographs showed an increase in diameter in 70% (59) of the grafts. There were seven fatigue fractures in six patients, but only two needed treatment.

Non-vascularised fibular transfer is a simpler, less expensive and a shorter procedure than the use of vascularised grafts and allows remodelling of the fibula at the donor site. It is a biological reconstruction with good long-term results, and a relatively low donor site complication rate of 16%.

Non-vascularised autogenous bone grafts have been used for the past 100 years, particularly for reconstruction after resection of a bone tumour. The first description of their use was in 1911,1 with Taylor, Miller and Ham2 achieving successful use of a vascularised fibular graft for the reconstruction of a limb defect in 1975.

The fibula is strong and may be used for reconstruction of large defects in bone due to tumour,3,4 and its use as a non-vascularised graft in such circumstances has been described.5,6 The danger of resorption and the lack of biological activity have been thought to be a disadvantage of non-vascularised grafts.7,8 We have evaluated the biological activity of non-vascularised fibular grafts in patients with musculoskeletal tumours. We have assessed the stability of these reconstructions with different methods of fixation at various locations, the influence of adjuvant chemotherapy and radiotherapy on union, incorporation with the host-bone and remodelling, and complications at the donor site.

Patients and Methods

Between 1976 and 2003, 31 patients had a reconstruction with a non-vascularised fibular graft after resection of a musculoskeletal tumour. There were 13 males and 18 females with a mean age of 29.8 years (6 to 72). We have reviewed them at a median follow-up of 5.6 years (3 to 26.7), excluding those with a follow-up of less than three years. The patients were evaluated systematically and functionally, according to the Musculoskeletal Tumour Society Score (MSTS).9 The patient’s characteristics are shown in Table I.

The grafts were harvested using a posterolateral approach with preservation of the periosteum. The grafts were used either for stabilisation of the pelvis after resection of the ilium or as an intercalary segment for reconstruction. The fibula was wedged in the bone or fixed with a screw or tension band wire (Fig. 1). In ten cases the reconstruction was stabilised in combination with a plate (Synthes, Oberdorf, Switzerland (Fig. 2). Depending on the size of the defect we used single, double or triple fibular grafts. Of the 31 patients, 20 were reconstructed with a single, seven with double and four with triple fibular grafts. The length of the fibular graft was between 4 cm and 23 cm (median 10, interquartile range (IQR) 8 to 13). The patients were followed up regularly until union was achieved. The radiographs were analysed to assess the size of the defect, and the length of the implanted graft, for evidence of union and for complications. In 16 patients, radiographs of the donor site were taken to evaluate remodelling of the fibula which was classified as complete, partial and none. Partial remodelling was recorded when
ossification was present along the periosteum but the fibula was thinner than it had been pre-operatively.

In the four triple fibular reconstructions we were not able to fully evaluate the third graft in two-plane radiographs.

We therefore evaluated the increase in diameter, as the primary end-point in 42 non-vascularised grafts with 84 graft-host junctions. We defined a fibular graft as biologically active when an increase in diameter was seen as measured by the hypertrophy index of De Boer and Wood.10

We compared the patients who received radiotherapy and/or chemotherapy with those who did not have additional treatment. We recorded the stability, mobility, local complications of the donor and host sites, remodelling of the fibula and the incidence of fatigue fractures.

At the end of the study two patients had died of metastatic disease and one of heart disease. One had a local recurrence of tumour at the femoral neck (case 23). This was widely resected and reconstructed with a total hip replacement four years after the first operation.

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* delayed union
Statistical analysis. The data is expressed as medians and quartiles for continuous end-points. Binary end-points are characterised by absolute and relative numbers of patients or grafts. Comparisons between patient subgroups are based on Fisher’s test for binary endpoints and on the two-sample Wilcoxon test for continuous end-points. A p-value < 0.05 indicates statistical significance. Statistical analysis was performed with SPSS software version 11.5 (SPSS Inc., Chicago, Illinois).
Results

Functional results

The functional results were evaluated in the remaining 28 patients using the MSTS. At final follow-up the median functional index was 77% (50% to 100%; IQR 63 to 90) in the lower limb in 23 patients and 80% (37% to 90%; IQR 59 to 87) in the upper limb in five.

Radiological results

Biological activity and hypertrophy. We found an increase of the diameter, demonstrating biological activity, in 59 fibular junctions (70%). Significant hypertrophy of more than 20% was detected in 40 (48%) of the graft junctions, no change was found in 35 (41%) and atrophy of the graft ends was seen in nine (11%).

The method of stabilisation had no influence on hypertrophy which was seen more frequently in patients under the age of 20 years (63%; 15 graft junctions vs 42%; 25 graft junctions, p = 0.006), in those without chemotherapy or radiotherapy (54%; 25 graft junctions vs 40%; 15 grafts junctions p = 0.195), in reconstructions in the upper limb (58%; 7 graft junctions vs 46%; 33 graft junctions, p = 0.537) and in grafts ≥ 12 cm in diameter (50%; 25 graft junctions vs 46%; 15 graft junctions; p = 0.821). These differences, however, were not statistically significant.

Union, delayed union and nonunion. Primary union at less than 12 months after operation was achieved in 41 of 46 grafts (89%). The median time to consolidation for primary union was 24 weeks (7 to 61; IQR 15 to 31). In three reconstructions, two single and one double, union was delayed with a median consolidation time of 61 weeks without the need for secondary procedures. In two cases (4%) of single fibular reconstruction one or more junctions of the fibular graft to the host bone failed to unite.

Additional treatment with chemotherapy or radiotherapy had a significant effect on primary union. All 25 grafts in 18 patients who did not receive additional therapy achieved union, in comparison to 76% (16 of 21) of patients who had additional treatment (p = 0.017).

Remodelling of the fibula at the donor site. Radiographs of the donor site were available in 16 patients at a median of 3.6 years (0.9 to 11.4; IQR 2.4 to 6.1) after surgery. Of these, 11 patients (69%) showed complete (5) or partial (6), remodelling of the fibula with the remaining five having no evidence of remodelling. The patients with complete or partial remodelling were significantly younger than those without, with a median age of 16 years (6 to 32; IQR 14 to 23) compared with 38 years (26 to 60; IQR 28 to 52) (p = 0.03).

Complications

Details of the incidence of complications encountered are listed in Table II.

Fatigue fracture. A fatigue fracture occurred in seven grafts (15%) in six patients. They occurred mainly after union of both graft junctions, except in one case where this happened before the junctions had been consolidated. Four of the six patients were asymptomatic and the fracture was identified retrospectively on radiographs taken at follow-up. The other two patients were treated conservatively with immobilisation. Union was achieved in one of the patients after four months. The fatigue fracture in the other failed to heal and was treated by internal fixation, which also failed. Union was eventually achieved after a further procedure using a vascularised pelvic bone graft with plate fixation (case 19).

There was a clinically relevant, but not statistically significant, difference in the incidence of fatigue fracture depending on the type of stabilisation used, with 19% (6)
vascularised grafts. In an experimental animal study bridg-vascularised grafts hypertrophied nearly as much as the et al found biological activity and hypertrophy in 32% of such grafts showed hypertrophy. Enneking movement of the ankle was 20˚ less than the opposite side. In another patient, combined muscle resulted in a significant improvement of the range of the muscles to the scar tissue. Operative release of the lateral malleolus and the tibia. One patient had adhesion of this was the result of harvesting the fibular graft more dis-
tally than usual. This patient later had a fusion between the donor site in five patients (16%). Two had peroneal nerve damage at the site of harvest of the fibular graft. One patient experienced a clinical decline post-operatively, while the other had a permanent nerve injury. One patient had instability of the ankle joint and a valgus deformity and this was the result of harvesting the fibular graft more dis-tally than usual. This patient later had a fusion between the lateral malleolus and the tibia. One patient had adhesion of the muscles to the scar tissue. Operative release of the muscle resulted in a significant improvement of the range of movement in the ankle joint. In another patient, combined movement of the ankle was 20˚ less than the opposite side.

Discussion
There are a number of recent reports of the successful use of vascularised fibular grafts, and non-vascularised grafts are now less commonly used. We expected to find a marked difference in the biological activity of the two types of graft because of the blood supply. Hypertrophy of vascularised fibular grafts as described in the literature varies between 37% and 90% compared with a mean of 32% in nonvascularised grafts. In an experimental animal study bridging segmental defects of the radius and ulna, nonvascularised grafts hypertrophied nearly as much as the vascularised fibulae. In clinical studies on vascular fibular grafts, the maximum degree of hypertrophy was achieved at a mean of 2 to 3 years. After 12 months only 28% to 43% of such grafts showed hypertrophy. Enneking et al found biological activity and hypertrophy in 32% of the non-vascularised fibular grafts, but did not take the radiological magnification into consideration. However, when the host site has a small diameter at the junction, such as in the radius, ulna, fibula or diaphysis of the humerus, a significant increase in the diameter of the donor fibula cannot be expected.

In our study 59 (70%) of the grafts had an increase in diameter. Hypertrophy of the graft of more than 20% was found in 40 (48%) of the graft junctions. The patient group was relatively young with a median age of 28 years. Younger patients have a tendency of earlier and faster graft hypertrophy (63% under 20 years), probably because of their higher capacity for remodelling and increased level of activity. Hsu et al found a statistically-significant difference in hypertrophy between the upper and lower limbs. Our results confirm this. Hypertrophy was more common in the presence of mechanical loading and was achieved earlier in younger patients and in grafts that were not internally fixed with an intramedullary nail or a plate. Fibular grafts longer than 12 cm and those without plate or nail fixation had a higher rate of hypertrophy because of the higher mechanical stress at the junctions.

A demonstration of secondary vascularisation was seen in two patients who sustained a fracture after trauma to an unsupported graft which healed with cast immobilisation after four months. Both developed callus formation, demonstrating that this autograft was functioning as vascularised bone with excellent biological activity. Yadav looked at three biopsies of a non-vascularised fibular graft during revisions. All three showed clear evidence of vascularisation.

The time to achieve union might be an important dif-
ference with vascularised grafts. Primary union of vascularised fibular grafts has been observed in 86% to 92% of cases at a mean of 4.5 to 12 months. In animal experiments, however, Dell et al and Brown found no substantial difference between non-vascularised and vascularised grafts in the time to consolidation or in the incidence of union. All proximal and distal fibular graft-host junctions were solidly united after three months in the dog fibula. Vascularised grafts were transiently stronger than conventional grafts in the first six months, but there was no difference thereafter.

The clinical results of non-vascularised fibular grafts after tumour resection confirm these experimental find-
ings. Enneking et al found primary union in 63% of the long bone reconstructions within the first 12 months and Yadav union after 8 to 10 months in 60%. We achieved primary union in 89% of the tumour-related reconstruc-
tions of the limbs and the pelvis in a median period of 24 weeks. Neither we nor Enneking et al found any correlation between the length of the non-vascularised fibular graft and the rate of healing. This has also been noted with vascularised fibular grafts.

Single fibular grafts have had a high rate of failure when used to reconstruct or stabilise segmental defects. In the series of Enneking et al the incidence of nonunion in single fibular grafts was 43%, but when compared with double grafts the difference was not statistically sig-
ificant. Our two nonunions were with single grafts and all patients with double or triple grafts achieved union. However, Yadav had a rate of nonunion of 8% with double fibular grafts but with rigid stabilisation.
Friedlender et al.22 studied the detrimental effects of chemotherapy on osteoblasts and thought that chemotherapy could impair fracture healing and the incorporation of bone allograft. It is well known that radiation in high doses inhibits osteogenesis.23 In our series, all patients with delayed or nonunion had received either radio- or chemotherapy. There was no difference between the effect of the two treatments. Shea et al.19 and El-Gammal et al.17 found no difference in union with chemotherapy but a significant negative influence of radiation.

There are papers suggesting that stress fractures of the fibular graft are common, occurring in between 26% and 40%.10,19 We found the incidence to be higher in grafts ≥ 12 cm. The risk of fatigue fracture increases with the length of the graft, the fixation, hypertrophy and the site.4,6,19

Complications of harvesting the fibular graft include injuries to the peroneal nerve, compartment syndrome, various local muscular problems and ankle instability. The proximal 4 cm of the fibula should be preserved to reduce the risk of nerve injury.24 The complication rate at the donor site in our series was 16% and for vascularised grafts has been reported to vary between 7% and 35%.18,20,23,26 It appears to be higher than for non-vascularised grafts whose complication rate has been reported to vary between 4% and 12%.5,6,27

Problems in the ankle after harvesting a fibular graft have been reported to range between 10% and 40%.19,28 Clinical studies have suggested that the distal 6 cm to 8 cm and the anterior syndesmosis should be preserved to maintain lateral stability of the ankle.29,30 Valgus of the ankle can develop in skeletally-immature patients after partial resection of the fibula.23,25 The patient in our series who developed instability with a valgus deformity of the ankle did so because procurement of the fibular graft was too distal. To avoid this, fusion of the distal fibula to the tibia with screws may be undertaken.19,25

We are not aware of reports concerning remodelling of the fibula after harvesting at the donor site. We found complete or partial remodelling of the fibula in 69%. This potential does not exist after harvesting the fibula with its vessel and the periosteum. Remodelling is also important for the prevention of tibial stress fractures which have been described after removal of a vascularised graft.31,32

Our results indicate the value of using non-vascularised fibular grafts to reconstruct or bridge bone defects after resections for tumour (Fig. 2). This simple, inexpensive and quick procedure does not require extensive training or a large number of operative personnel. The results are comparable to those with vascularised grafts. The disadvantage may be the somewhat longer time to union, but under favourable conditions this difference does not seem to be important. The advantages include a shorter operative time and lower morbidity at the donor site. The resected part of the fibula may be regenerated completely or in part from the periosteum, especially in younger patients. Non-vascularised fibular grafts are a useful alternative to vascularised grafts especially where there is a good cover with soft tissue and good blood supply. Vascularised grafts should be used primarily in the lower leg and the forearm and when stabilisation is difficult, such as when the defect is within the epiphysis very close to the joint.

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