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Vascularised free fibular flap in bone resection and reconstruction☆

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Summary This paper compares allograft alone and in combination with vascularised free fibular flaps (FFF) to reconstruct long bone defects after tumour excision.

We present 33 cases, 21 of these patients had reconstruction with an allograft alone as the initial procedure. Nine patients underwent reconstruction with FFF plus allograft plus iliac crest bone graft (ICG), two patients underwent reconstruction with a FFF and ICG and one patient underwent reconstruction with an allograft, a pedicled fibular flap and a FFF. The allograft was obtained from the Queensland Bone Bank and had been irradiated to 25 000 Gy.

In our experience ($N=21$) the complication rates with allograft alone were: delayed union 3, nonunion 7, fractured allograft 6, infection requiring resection of the allograft 3, other infections 2. The revision rate was 48% (10 cases of which five required a free fibular flap) and an average of 1.8 revision procedures were required. In the lower limb cases, the mean time to full weightbearing was 20 months and 40% were full weightbearing at 18 months. We felt that the high complication rate compared with other series may have been related to the irradiation of the graft.

FFFs were used in 18 cases, 12 cases were primary reconstructions and six were revision reconstructions. The mean fibular length was 19.4 cm (range 10–29 cm).

There were no flap losses and the FFF united at both ends of 11 of 12 primary reconstruction cases. One case had nonunion at one end, giving a union rate of 96% (23 of 24 junctions). When a FFF was used in combination with an allograft as a primary reconstruction, the allograft nonunion rate was 50% (five of 10 cases). The mean time to full weightbearing in the lower limb cases was 7.5 months and 100% were full weightbearing at 18 months.

The FFF hastens time to full weightbearing but does not appear to affect the complication rates of allograft. The number of revision procedures required is reduced in the presence of a FFF and is the latter is a useful technique for the salvage of refractory cases.

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Primary high-grade malignant tumours of long bones include osteosarcoma, chondrosarcoma, Ewing's sarcoma, adamantinoma and malignant fibrous histiocytoma. In the past, these tumours were treated by limb amputation. Although these procedures were occasionally curative, they caused significant local morbidity and handicap. Advances in neoadjuvant chemotherapy have improved the prognosis of these patients by controlling, and in some cases eliminating, local recurrences and metastases. Furthermore, it is now possible to perform limb-salvage procedures after en bloc resection of tumours.

The options for reconstruction include endoprosthesis, allograft, non-vascularised autograft and vascularised autograft, or combinations of these above techniques. Tailor-made custom prostheses are manufactured to replace almost any part of the skeleton. The advantages of prosthetics include immediate stability and function with resultant early ambulation and full weightbearing when used in lower limb reconstruction. Unfortunately, they are prone to mechanical failure, implant or bone fracture, infection, dislocation and loosening.

Allografts may be used as intercalary grafts, osteoarticular grafts or as grafts to replace entire bones. Revascularisation of allografts is a slow, and often incomplete process. Autogenous (non-vascularised) cancellous or cortico-cancellous bone grafts contribute cells capable of new bone formation. Unfortunately, these grafts are unsuitable for defects greater than 6–8 cm in length and it is not possible to reconstruct a joint using a non-vascularised autograft. The term 'creeping substitution' has been coined (Phemister 1914) to describe the simultaneous processes of resorption and deposition which occur in osteogenesis and repair of bones. Allografts and devascularised autografts really provide a framework for inductive creeping substitution. Therefore, with allografts and devascularised autografts the processes of revascularisation and creeping substitution weaken the grafts, so predisposing to delayed union, nonunion, infection, fatigue fracture and resorption.

A vascularised autograft heals by primary union and not by creeping substitution. As such it represents the ideal bone graft because it can heal the loss of a large segment of bone, it provides viable autogenous bone, which actively participates in the healing process, it unites quickly, and remains reliably organised. Also it is alive and can resist and avoid contamination and defies resorption. It heals as a double fracture and not by the processes of creeping substitution. By virtue of its vascularity it is able to heal in a sclerotic bed. In skeletally immature individuals, incorporation of the proximal fibular metaphysis in a reconstruction can result in continued growth of the autograft. Finally, vascularised autografts are able to undergo hypertrophy resulting in increased strength.

Unfortunately, the strength of a vascularised fibular flap maybe insufficient until hypertrophy occurs. This has been reported to occur on average 18 months after surgery.[1] Furthermore, hypertrophic bone fractures have been reported and therefore some advocate protecting the vascularised fibular flap in the lower limb for the first few years after implantation.

Combining allografting with vascularised autografting should theoretically improve the outcome by combining the mechanical advantages of an allograft with the biological properties of a vascularised autograft. The vascularised autograft would hypertrophy and by placing a custom made allograft around the vascularised fibular flap, good stabilisation and protection against longitudinal stress should be achieved. This paper presents our experience of using allograft alone and in combination with a vascularised free fibular flap for reconstruction after en bloc tumour resection.

Patients and methods

This study assessed the clinical features of all patients undergoing long bone resection with a reconstruction using allograft alone and in combination with a vascularised free fibular flap. The earlier cases were assessed retrospectively and the latter cases were assessed prospectively. For the purposes of this study, a delayed union where there was no evidence of any callus formation or loss of definition of the osteosynthesis site at 6 months and/or the osteosynthesis was not fully united at 12 months.

Results

Allograft experience

A total of 21 cases underwent reconstruction with allograft alone (Table 1).

A total of 10 patients required revision of their allograft reconstruction. This gives a revision rate of 48% ($N=21$). Two patients required amputation due to infection and infection and recurrence of the tumour, respectively. Five cases required revision

with a free fibular flap. One patient required a rotational osteotomy. A further patient required a cement spacer and then a prosthesis for an infected allograft. One patient required replating and repeat autogenous bone graft. There was often delayed time to full weightbearing (Table 2).

Overall complication rate with allografts was 15/21 patients or 71%, only 6/21 patients had no complications (29%). Overall complication rate of primary reconstructions using a free fibular flap was 61.5% (8/13) with 38.5% of patients (5/13) experiencing no complications.

Reconstruction using free fibular flap

Nineteen cases have undergone reconstruction with a free fibular flap. These cases were performed between the period September 1985 and September 2001. One of these patients who received a free fibular flap and iliac crest autograft died 3 months after surgery and in this patient we were unable to assess the union of the free fibula and therefore this case has been excluded from further discussion.

Twelve were male and six were female. They had a mean age of 24.6 years (range 13–63 years).

Eight cases had resection of an osteosarcoma, of which two were parosteal. There were four chondrosarcomas, two Ewing's sarcomas, two adamantinomas, one giant cell tumour and one malignant fibrous histiocytoma.

Thirteen of these cases involved the lower limb with seven involving the tibia, six the femur. Five of the cases involved the humerus.

The mean fibular length was 194 mm. Data on length of the fibula was only present in 13 of the 18 cases. The range was 100–290 mm.

Additional reconstruction included three pedicled gastrocnemius flaps and two pedicled latissimus dorsi flaps.

Twelve of the cases were of primary reconstruction and six of the cases were of secondary reconstruction.

Table 1 Complication rates with allograft reconstruction alone

	% Complication	No. of patients
Delayed union	14	3
Nonunion	33	7
Fracture of allograft	29	6
Infection requiring resection of allograft	14	3
Other infections	10	2
Total number		21

Table 2 Allograft reconstruction alone compared with a combination of allograft and free fibular flap

Complication	Allograft only	Free fibula +allograft
Number of cases	21	10
Delayed union	14%	0
Nonunion allograft	33%	50%
Nonunion fibula	-	10%
Fractured allograft	29%	10%
Infections requiring removal of allograft	14%	10%
Lower limb		
Time to full weightbearing (months)	20 (14 cases)	7.5 (8 cases)
% Full weightbearing (18 months)	40%	100%
Revision rate	48%	50%
Union rate (1 year post revision)	33%	100%
Number of revisional procedures required	1.8	1.0

The primary reconstruction treatments employed included nine cases with allograft, free fibular and non-vascularised autograft; one case of allograft and pedicled fibula in addition to free fibula, and two cases with iliac crest autografts and free fibula flap without the use of allograft.

Complications with primary reconstructions using free fibular flaps

Of the 18 fibular flap cases, 12 were primary reconstructions, 10 of which were accompanied by an allograft.

Of the 12 cases with a primary fibular flap, there were no cases of loss of the fibular flap. There was one case of a nonunion giving a union rate of the fibular flap of 92% (11 of 12 Patients). Of the 24 fibular flap junctions, union was achieved in 23 (96%). In the 10 cases with an allograft, the allograft nonunion rate was 50% (five of 10 cases). There were no donor site related complications.

Eight patients in this group had lower limb tumours. All were full weightbearing at 18 months. The average time to full weightbearing was 7.4 months (226 days, range 5–18 months).

In the 10 cases where free fibular flap and an allograft combination was employed, the revision rate was 50% (five of 10 cases). The revision consisted of a bone graft to the nonunion of the allograft in four of the five cases. One further case required medialisation of the fibula for a nonunion of the allograft. In this latter case, the patient had

both a pedicled and free fibular flap used for reconstruction. The allograft was later excised and the only remaining weightbearing strut in that patient was the free fibular flap. He had continuing sepsis. His fibular flap fractured and he went onto an amputation.

Revision with free fibular flap

A total of six cases underwent secondary revision using the free fibular flap. Five of these cases were for lower limb and one for upper limb reconstruction. Five of these cases had a previous failed allograft. Five had nonunion of the allograft. Two of the cases also had fractures involving allograft. A further case had a failed free fibular flap from elsewhere. In two of the six cases the revision with a free fibular flap was the primary revision employed. In three of the six cases, the revision with a free fibular flap was the second revision that was employed and in the one case it was the third revision employed.

The mean union with a free fibular flap was 10 months (range 5–14 months). Only one of six cases required more than one revision and this case required two free fibular flaps to a nonunion of a humeral defect.

Discussion

The use of free fibular flap has been widespread in both orthopaedic and plastic surgical practice since it was first described by Taylor et al. in 1975.[2]

The results of our study show that complications with allograft are numerous and the complications are sufficiently disabling that it is worth considering other reconstructive modalities. We felt that the irradiation of the allograft might have added to the difficulties by reducing strength and by increasing nonunion rates.

The presence of a free fibular flap in addition to an allograft does not appear to change the complication rate of the allograft reconstruction. The complication rate is as high with allograft and free fibular flap as with allografts alone. However, the presence of a free fibular flap does appear to hasten the time to full weightbearing even in the face of these complications. On those occasions where further revisional procedures are required, the presence of a free fibular flap appears to reduce the number of secondary procedures required (1.0 versus 1.8 procedures).

The salvage with a free fibular flap of a failed primary reconstruction is a useful technique, the mean union occurring within 10 months of the revision. The number of further revision procedures required after use of a free fibula as a salvage procedure is much less than with other modalities of reconstruction.

The numerous complications of using allograft as the sole modality of treatment are well recorded in the literature, showing that our high complication rate is commonly experienced by others.[3–14] The incidence of the various complications is summarised with our complication rates shown in parentheses: delayed union 51–57% (14%), nonunion 10–32% (33%), fracture of allograft 11.3–58% (20%), infections 3.6–30.2% (24%), complication rate 46.5–75% (71%).

Our results compare favourably with those in the literature regarding the use of free fibular flaps in long bone reconstruction, both as the sole modality and in combination with allografts.

The mean fibular length in this series of 194 mm is the longest recorded, with the range in previous reports being 119–189 mm[15–19] (Hsu 1997, Ihara 1998, Moore 1983, Wieland 1983, Ozaki 1997). None of our cases experienced microvascular complications, comparing with the literature rates of up to 22% flap revision rate for microvascular complications.[16] No free fibular flaps were lost in our series, whereas flap loss rates as high as 15.4% are recorded.[20]

In series using free fibular flaps as the sole modality, fibular union occurs in 74–100% of cases reported, our rate of 96% is within this range.[15,16,20,21] The incidence of delayed union is 16.7–45%.[15,20,22] The infection rates are 10–15.4%.[15,23] The incidence reported in the literature of stress fractures with free fibular flaps alone is greater than in our series where the fibular flaps were combined with allografts. The stress fracture rates with free fibular flaps alone is 7.7–22.2%.[15,16,23,24] The overall complication rate with free fibular flaps alone is of the order 50–54%.[15,20] There is only one study which addresses the mean time to full weightbearing and this was the series of nine patients by Ihara[16] in 1998 which found this to be 5 months.

There are three series in the literature using vascularised fibular flaps in combination with allografts.[3,19,25] Donati et al. experienced a nonunion rate of the allograft of 45% (nine of 20 cases). The latter group also reached the same conclusion as in our series that 'using a vascularised fibula to augment the construct did not prevent allograft fractures', however, they found that most of the fractures were fatigue in nature and treatable by conservative means.

The allografts in the Donati series were not

irradiated and were stored at −80°. The allografts in our series received irradiation. It has been shown that high-dose irradiation to bone allografts is associated with a significantly higher rate of fracture than similar reconstructions using nonirradiated allografts.[26] Unrelated to our findings and subsequent to this study, the source used to supply the allograft has subsequently reduced the radiation dosage protocol to the allografts from 25 to 15 kGy.

Ozaki et al.[19] used centralization of the ipsilateral fibula after tibial resection and combined it with an allograft. The fatigue fracture rate was 33% and a further 25% experienced deformity. The presence of the fibula in this group does not appear to have affected the allograft complication rate.

Ceruso et al.[25] describe their experience with 52 reconstructions using vascularised free fibular flaps combined with allografts. The mean time to consolidation was 2.7 months for the free fibular flap, and 8 months for the allograft. Full weightbearing was achieved after an average time of 13.7 months (range 3.5–24 months). They also experienced a high fracture rate of the allograft of 21% (11 of 52). The nonunion rate of the osteotomy site in the latter series was 5.7% (two of 35 cases) for tibial reconstruction, and an infection rate of 8.6% (three of 35 cases).

The use of post operative chemotherapy has been shown to increase the rate of nonunion of allografts.[13] A total of seven patients in our series received both pre and post operative chemotherapy, six had primary reconstructions and one a secondary reconstruction. Of the six patients with a primary reconstruction, one died too soon to assess the true outcome. The complication rates of the other five patients were: nonunion of allograft 60%, nonunion of fibular flap 20%, fractured allograft 20%, infection 20%, wound breakdown 20%. These complication rates are similar to the whole group, but the number of patients in the chemotherapy group is too small to derive any conclusions.

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