We assessed the results of 17 limb-salvage procedures using osteoarticular allografts after wide resection of high-grade malignant bone tumours. All patients received chemotherapy. At the five-year follow-up, three patients had died from metastases. The allografts survived for five years in only seven patients all of whom had good function, ranging from 73% to 90% of normal. The allografts were removed because of fracture in seven patients and infection in one, and in all of these a second limb-salvage procedure was undertaken.

With such a low rate of survival of osteoarticular allografts, we believe that their use in the management of high-grade malignant bone tumours should, at best, be considered a temporary solution.

We have evaluated the use of osteoarticular allografts in the proximal humerus, distal femur and proximal tibia over a period of five years.

Patients and Methods

Between 1990 and 1994, ten boys and seven girls with high-grade malignant tumours of metaphyseal bone had reconstruction with an osteoarticular allograft after wide resection of the tumour. The mean age of the 17 patients at the time of resection was 14 years (11 to 19). Two had a Ewing’s sarcoma and 15 an osteosarcoma. Adjuvant treatment was completed in accordance with COSS\(^5\) and CESS\(^6\) protocols. The proximal humerus was the site of the primary tumour in six patients, the distal femur in four, and the proximal tibia in seven. After resection, the mean length of the osseous defect was 15 cm (11 to 28).

We obtained allografts from the Bone Bank in Münster or from the Bio Implant Service of The Netherlands Bone Bank.
Bank Foundation. Harvesting and storage techniques compli-
ced with the standards of the American Association of Tissue Banks. The grafts were fresh frozen and cartilage was preserved with 10% dimethyl sulphoxide. Of the 17 allografts, 12 were irradiated. To match sizes, we used anteroposterior and lateral radiographs of the allograft and of the host bone. Rhesus compatibility was ensured.

In all except our first three cases we filled the intra-
medullary canal of the allograft with bone cement to
strengthen it and to prevent the formation of undrained cavities. Dynamic compression plates were used for osteosynthesis. We reattached ligaments and joint capsules to approximate to anatomical normality and to achieve stability. We covered the allograft with a local muscle flap using, for example, the medial gastrocnemius for the proximal tibia.

The mean follow-up was for 5.5 years (5.1 to 6.2). Any condition which made further surgery necessary was recorded as a complication. In order to compare the use of allograft with other reconstructive procedures, we deter-
mined whether the reason for failure lay in the allograft and/or implant, the interface, infection or other causes. We used the functional evaluation system of Enneking et al.\(^7\)

**Results**

No primary tumours recurred locally, but at the five-year follow-up three patients had died from metastases. In one of these (Table I, case 11) the allograft had failed after 2.3 years and we had implanted a prosthesis. We were therefore able to analyse the results of 15 osteoarticular allografts followed up for at least five years or until their removal.

Only seven allografts survived five years. Fractures occurred in five of seven proximal tibial grafts and in two of six proximal humeral grafts in the epiphyseal or metaphyseal part of the allograft. A distal femoral allograft was removed (Table I, case 16) due to deep infection. In all cases it was possible to undertake a second limb-salvage procedure. We implanted a prosthesis in seven patients and carried out a second osteoarticular allograft in one (Table I).

Radiographs showed union at nearly all interfaces, but when we examined the interface of removed grafts we sometimes found incomplete union with fibrous tissue and focal sclerosis (Fig. 3). Without removing the allograft, we successfully treated three patients with nonunion by an additional autogenous bone graft.

Other complications included contractures and sloughing of the skin, the treatment of which required eight additional surgical procedures. Only four grafts survived without further operation.

The seven patients whose allografts survived five years had good function with a mean of 85% of normal (73 to 90).

**Discussion**

The oncological goal of local control of the tumour was achieved and there was no local recurrence five years after wide resection of the lesion. Three of 17 patients died from metastases. This is comparable to other results after the use of COSS and CESS protocols.\(^5,6\)

Other studies of the use of osteoarticular allografts for reconstruction have involved a variety of pathologies, adjuvant treatments and surgical techniques. By focusing clearly on a well-defined group of patients, our study has allowed assessment of the merits of the use of reconstructive osteoarticular allografts in the treatment of high-grade malignant bone tumours.

The main reason for failure of the allograft was fracture which occurred in eight (47%). There are no directly comparable studies, but Mankin et al\(^8\) reported an incidence of fracture of 19% in a large series of allograft reconstructions of a different type. We classified all mechanical failures of the allograft as fractures, but some authors distinguish between fracture, subchondral collapse

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| Case | Site of defect | Age at time of surgery | Duration of irradiation (yr) | Indication | Number of revision procedures | Length (cm) | Time to revision allograft (yr) | Second follow-up (yr) | Last functional score | Proximal humerus | Distal femur | Proximal humerus | Proximal humerus | Proximal humerus | Proximal humerus | Proximal humerus | Proximal humerus | Proximal humerus | Proximal humerus | Proximal humerus | Proximal humerus | Proximal humerus | Proximal humerus | Proximal humerus | Proximal humerus |
|------|----------------|------------------------|-----------------------------|------------|-----------------------------|-------------|------------------------------|----------------------|-------------------|----------------|-------------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|
| 01   | Proximal humerus | 15                     | Yes                          | Interface  | 5.1                          | 13.0        | 3.0                          | 12.6                | Yes              | 14             | 14           | 10             | 15             | 16             | 15             | 16             | 16             | 16             |
| 02   | Proximal humerus | 16                     | No                           | 13.0       | 0.8                          | 0.0         | 13.9                         | 15.0                | Yes              | 14             | 14           | 10             | 15             | 16             | 15             | 16             | 16             | 16             |
| 03   | Proximal humerus | 14                     | No                           | 12.0       | 0.0                          | 0.0         | 11.3                         | 11.3                | Yes              | 14             | 14           | 10             | 15             | 16             | 15             | 16             | 16             | 16             |
| 04   | Proximal humerus | 11                     | Yes                          | Fracture   | Prosthesis                   | 1           | 1.0                          | 3.7                 | 2.0              | 11             | 11           | 10             | 15             | 16             | 15             | 16             | 16             | 16             |
| 05   | Proximal humerus | 14                     | Yes                          | Fracture   | Allograft                    | 3           | 1.0                          | 1.0                 | 1.0              | 11             | 11           | 10             | 15             | 16             | 15             | 16             | 16             | 16             |
| 06   | Proximal humerus | 12                     | Yes                          | Fracture   | Prosthesis                   | 3           | 1.0                          | 1.0                 | 1.0              | 11             | 11           | 10             | 15             | 16             | 15             | 16             | 16             | 16             |
| 07   | Proximal humerus | 13                     | Yes                          | Fracture   | Prosthesis                   | 3           | 1.0                          | 1.0                 | 1.0              | 11             | 11           | 10             | 15             | 16             | 15             | 16             | 16             | 16             |
| 08   | Proximal humerus | 10                     | Yes                          | Fracture   | Prosthesis                  | 5           | 1.0                          | 0.3                 | 0.0              | 11             | 11           | 10             | 15             | 16             | 15             | 16             | 16             | 16             |
| 09   | Proximal humerus | 11                     | Yes                          | Fracture   | Prosthesis                  | 3           | 1.0                          | 1.0                 | 1.0              | 11             | 11           | 10             | 15             | 16             | 15             | 16             | 16             | 16             |
| 10   | Proximal humerus | 11                     | Yes                          | Fracture   | Prosthesis                  | 3           | 1.0                          | 1.0                 | 1.0              | 11             | 11           | 10             | 15             | 16             | 15             | 16             | 16             | 16             |
| 11   | Proximal humerus | 12                     | Yes                          | Fracture   | Prosthesis                  | 3           | 1.0                          | 1.0                 | 1.0              | 11             | 11           | 10             | 15             | 16             | 15             | 16             | 16             | 16             |
| 12   | Proximal humerus | 13                     | Yes                          | Fracture   | Prosthesis                  | 3           | 1.0                          | 1.0                 | 1.0              | 11             | 11           | 10             | 15             | 16             | 15             | 16             | 16             | 16             |
| 13   | Proximal humerus | 11                     | Yes                          | Fracture   | Prosthesis                  | 3           | 1.0                          | 1.0                 | 1.0              | 11             | 11           | 10             | 15             | 16             | 15             | 16             | 16             | 16             |
| 14   | Proximal humerus | 12                     | Yes                          | Fracture   | Prosthesis                  | 3           | 1.0                          | 1.0                 | 1.0              | 11             | 11           | 10             | 15             | 16             | 15             | 16             | 16             | 16             |
| 15   | Proximal humerus | 13                     | Yes                          | Fracture   | Prosthesis                  | 3           | 1.0                          | 1.0                 | 1.0              | 11             | 11           | 10             | 15             | 16             | 15             | 16             | 16             | 16             |
| 16   | Proximal humerus | 14                     | Yes                          | Fracture   | Prosthesis                  | 3           | 1.0                          | 1.0                 | 1.0              | 11             | 11           | 10             | 15             | 16             | 15             | 16             | 16             | 16             |
| 17   | Proximal humerus | 15                     | Yes                          | Fracture   | Prosthesis                  | 3           | 1.0                          | 1.0                 | 1.0              | 11             | 11           | 10             | 15             | 16             | 15             | 16             | 16             | 16             |

Table I. Details of 17 patients with malignant bone tumour who had limb-salvage procedures using an osteoarticular allograft.
and graft resorption. We view these events as parts of a process which begins at implantation. Resorption of dead allograft leads to weakening of the bone and possible subchondral collapse or fracture. New formation of bone may follow resorption, strengthening the graft. Enneking and Mindell and Tomfort, Bloem and Mankin have reported instances of healing of allograft fractures. Despite bracing the limb for over a year, we did not observe this. All fractures developed in the metaphyseal cancellous region of the allograft, which seems to be its weakest part. In the allografts which we removed, the cortical region was intact, but the cancellous part had softened and grown weak.

Irradiation can increase the risk of fracture. There are reports that irradiation of more than 30 000 Gy reduces torsion and bending strength to 65% of normal, while breaking strength remains at 80% to 90% with radiation of less than 30 000 Gy. In our series the Bone Bank of Münster gave 26 000 Gy and the BioImplant Service of The Netherlands 15 000 Gy; the primary stability of the 12 irradiated grafts was almost normal. Secondary long-term stability is more important because of the process of resorption, subchondral collapse and fracture.

Nonunion between the host and interface occurred in three cases (20%) which is similar to that reported in other studies. The incidence of infection in previous series ranged from 7% to 17%, although all our patients received chemotherapy, only one developed infection. It seems that covering the graft with soft tissue, cementing the intramedullary canal and irradiating the allograft all serve to reduce the risk of infection.

The functional results were good. We used the functional evaluation system of Enneking et al and not the scoring system designed specifically for allograft reconstruction, because it does not allow a comparison between different reconstruction procedures and, in assessing failure, does not distinguish between limb loss and death.

Mankin et al showed that the underlying pathology affects the outcome of allograft reconstruction. The results are better in benign lesions than in highly malignant tumours, and osteoarticular allografts are less successful than intercalary allografts.

This is the first specific analysis of the use of osteoarticular allograft as a limb-salvage procedure in the treatment of high-grade malignant bone tumours, and the results are not encouraging. Only seven of 15 allografts survived five years, and only four needed no additional surgery. As more effective adjuvant treatment develops for osteosarcoma and Ewing’s sarcoma, the number of long-term survivors is increasing. There is a need for a more lasting solution to the problem of limb reconstruction. Reconstruction with an osteoarticular allograft seems to be a very short-term measure, and we advise that it be used with caution.

References


Fig. 3

The allograft interface, which is not united, shows fibrous union with focal sclerosis.


