MASSIVE FEMORAL ALLOGRAFTS FOLLOWED FOR 22 TO 36 YEARS
REPORT OF SIX CASES

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Six massive femoral allografts followed up for 22 to 36 years are described. Three were intercalary, two were osteoarticular and one was a total femoral replacement. Their functional rating according to the Musculoskeletal Tumor Society System (Enneking 1987) averaged 82% (56 to 100). The radiographic score averaged 75% (48 to 100). Four allografts had suffered fractures, but three of these had later united to give good final scores. Our study shows that massive femoral allografts can function well for as long as 36 years.

MATERIAL AND METHODS
Five of the patients had received osteoarticular or intercalary allografts of at least one-third of the total femoral bone mass not less than 22 years ago. The mean follow-up was 27 years (22 to 36). Some 33 massive allografts were performed during the period 1954 to 1968 by, or under the supervision of Dr Ottolenghi. Only the six with over 20-year follow-up and grafts of the femur are reviewed here. The grafts had been obtained from cadaveric donors, and were stored at −20°C for two to 12 months before implantation. No attempt was made to ensure cartilage viability. The clinical data of the six patients are summarised in Table I and the site and extent of the grafts are shown in Figure 1.

The patients were evaluated using the functional and radiographic Musculoskeletal Tumor Society (MSTS) rating system (Enneking 1987). Functional evaluation was based on six criteria: pain, function, patient acceptance, need for external supports, walking ability and gait. A score was calculated by adding the values for all criteria, and the final rating was determined by expressing this figure as a percentage of the maximum attainable score.

Radiographic evaluation was based on eight criteria: healing of proximal and distal osteotomies, contour of the graft, graft fixation, graft density, graft diameter, joint stability, and joint changes. The maximum rate for this system was also 100%

Complications included four allograft fractures, all of which occurred during the first two years after grafting. Three of them needed at least one further operation with additional autografting but all healed. The fourth, in the neck of a total replacement, remained untreated and resulted in established nonunion. The two osteoarticular

Fig. 1
Case 1. Figure 2a – Radiograph of the femur of a 16-year-old boy with a juxtacortical chondrosarcoma. Figure 2b – Radiograph of the excised bone. Figure 2c – Immediately after massive allografting and arthrodesis of the knee. Figure 2d – Thirty-six years later. The patient had been reoperated, renailed and a further autograft added, to treat an allograft fracture one year after the first procedure (radiographic score 90%; functional rating 86%).

Table I. Details of six patients treated by massive bone allografts

<table>
<thead>
<tr>
<th>Case</th>
<th>Age (yr) at operation</th>
<th>Sex</th>
<th>Year of transplant</th>
<th>Diagnosis</th>
<th>Site and size of allograft</th>
<th>Type of reconstruction</th>
<th>Complications</th>
<th>Length of follow-up (yr)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>16</td>
<td>M</td>
<td>1954</td>
<td>Juxtacortical chondrosarcoma</td>
<td>Distal femur</td>
<td>Intercalary arthrodesis</td>
<td>Fracture</td>
<td>36</td>
</tr>
<tr>
<td>2</td>
<td>16</td>
<td>F</td>
<td>1959</td>
<td>Avascular necrosis</td>
<td>Femoral head</td>
<td>Osteoarticular</td>
<td>Osteoarthritis</td>
<td>27</td>
</tr>
<tr>
<td>3</td>
<td>16</td>
<td>M</td>
<td>1964</td>
<td>Juxtacortical chondrosarcoma</td>
<td>Proximal femur</td>
<td>Intercalary</td>
<td>Fracture</td>
<td>26</td>
</tr>
<tr>
<td>4</td>
<td>38</td>
<td>F</td>
<td>1957</td>
<td>Hydatidosis</td>
<td>Whole femur</td>
<td>Hip osteoarticular</td>
<td>Hip fracture</td>
<td>26</td>
</tr>
<tr>
<td>5</td>
<td>32</td>
<td>F</td>
<td>1968</td>
<td>Giant-cell tumour</td>
<td>Distal femur</td>
<td>Osteoarticular</td>
<td>Genu valgum</td>
<td>22</td>
</tr>
<tr>
<td>6</td>
<td>24</td>
<td>M</td>
<td>1968</td>
<td>Ewing's sarcoma</td>
<td>Femoral diaphysis</td>
<td>Intercalary</td>
<td>Fracture</td>
<td>22</td>
</tr>
</tbody>
</table>

Case 2. Figure 3a – Postoperative radiograph of an osteoarticular allograft of the femoral head, implanted for avascular necrosis after femoral neck fracture in a 16-year-old girl. Figure 3b – Radiograph 27 years later shows some osteoarthritis. The patient underwent a total hip replacement (radiographic score 77%; functional score 56%). Figure 3c – Photomicrograph showing articular cartilage and subchondral bone with viable osteocytes in vascularised marrow spaces (haematoxylin and eosin × 180). Figure 3d – One of the marrow spaces at higher magnification showing capillaries with erythrocytes and viable osteocytes in the bone matrix (haematoxylin and eosin × 350).
MASSIVE FEMORAL ALLOGRAFTS FOLLOWED FOR 22 TO 36 YEARS

Table II. Functional evaluation of six patients treated by massive bone allografts according to the MSTS rating system

<table>
<thead>
<tr>
<th>Case</th>
<th>Pain</th>
<th>Function</th>
<th>Patient acceptance</th>
<th>Supports</th>
<th>Walking ability</th>
<th>Gait</th>
<th>MSTS rating* (per cent)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>None</td>
<td>Recreational restriction</td>
<td>Enthusiastic</td>
<td>None</td>
<td>Unlimited</td>
<td>Minor cosmetic limp</td>
<td>86</td>
</tr>
<tr>
<td>2</td>
<td>Moderate</td>
<td>Partial disability</td>
<td>Satisfied</td>
<td>None</td>
<td>Limited</td>
<td>Minor cosmetic limp</td>
<td>56</td>
</tr>
<tr>
<td>3</td>
<td>None</td>
<td>No restriction</td>
<td>Enthusiastic</td>
<td>None</td>
<td>Unlimited</td>
<td>Normal</td>
<td>100</td>
</tr>
<tr>
<td>4</td>
<td>None</td>
<td>Partial disability</td>
<td>Satisfied</td>
<td>One cane</td>
<td>Limited</td>
<td>Major cosmetic limp</td>
<td>56</td>
</tr>
<tr>
<td>5</td>
<td>None</td>
<td>Recreational restriction</td>
<td>Enthusiastic</td>
<td>None</td>
<td>Unlimited</td>
<td>Minor cosmetic limp</td>
<td>93</td>
</tr>
<tr>
<td>6</td>
<td>None</td>
<td>No restriction</td>
<td>Enthusiastic</td>
<td>None</td>
<td>Unlimited</td>
<td>Normal</td>
<td>100</td>
</tr>
</tbody>
</table>

* see text

Case 3. Figures 4a - Radiographs of a 16-year-old boy showing a juxta-cortical chondrosarcoma. Figures 4b,c - Radiographs taken 26 years after massive allografting of the excised proximal femoral shaft (radiographic score 93%; functional score 100%).

Case 4. Figures 5a, b - Radiographs of a 38-year-old woman with hydatid disease involving the whole femur. Figure 5c - Twenty-six years after a total femoral allograft and arthrodesis of the knee, showing a stress fracture of the femoral neck. Figure 5d - The knee arthrodesis at the same time (radiographic score 48%; functional score 56%).
allografts both developed degenerative changes. One was symptomatic and needed total hip replacement 27 years after implantation, when the patient was 43 years old. The osteoarticular allograft of the knee required a high tibial osteotomy to correct malalignment one year after the transplantation. The knee showed degenerative changes but was asymptomatic 22 years after the original operation.

RESULTS

The results of the functional and radiographic evaluations are given in Tables II and III. The functional rating averaged 82% (56 to 100). Two intercalary diaphyseal allografts rated 100% and one knee osteoarticular graft 93%.

Radiographic evaluation showed mature callus at junction sites with no evidence of failed union in any patient. All the allografts showed some degree of cortical erosion, but in only one case was this severe (case 4). The final radiographic score for the whole group averaged 75% (48 to 93). The two intercalary diaphyseal grafts had the best scores (case 1, 90%; case 3, 93%).

The radiographic appearances of the six cases are shown in Figures 2 to 7.

DISCUSSION

The first clinical results of massive bone allografts were reported by Lexer (1925). As a result of much basic research (Chalmers 1959; Burwell 1963; Elves 1974) and the development of methods of bone storage, allograft techniques were widely adopted in orthopaedic surgery (Czitrom et al 1986). In the 1960s the procedure was reported by Ottolenghi (1966) and Parrish (1966) and in 1982, Ottolenghi, Muscolo and Maenza described a series of transplants followed for a minimum of five years. More recently, Mankin, Gebhardt and Springfield (1989) have reported a large series of patients followed for an average time of 50 months and a maximum of 17 years.

There have been no reports of patients followed for more than 20 years.

The functional analysis of our patients showed that five had no pain and that all were either enthusiastic about or satisfied with the results of their treatment. Walking ability was unlimited in four and in two patients (cases 3 and 6) functional ability was evaluated as 100%. Both of these had intercalary allografts, and both had suffered early fractures of the graft. In most series in the literature the best results were from intercalary allografts because of the absence of joint problems such as laxity, degenerative changes and pain (Malinin, Martinez and Brown 1985; Loty 1988).

Only two of our patients were rated functionally below 60%. One who had received her total femoral allograft 26 years before, had limited walking ability but no pain. The other had an osteoarticular femoral head graft which had to be converted to a total hip arthroplasty 27 years later (Fig. 3). The specimen retrieved at operation showed areas of articular cartilage still present in the weight-bearing zone (Figs 3c,d).

The first patient in the series, with the longest follow-
MASSIVE FEMORAL ALLOGRAFTS FOLLOWED FOR 22 TO 36 YEARS

up (36 years), had a functional rating of 86% because of his limited walking ability due to the knee arthrodesis, but had no pain and was enthusiastic about his result.

None of the osteotomies failed to unite and none needed secondary operations at the osteotomy site. In all there was mature callus and the line of union was invisible on the radiographs. Case 4 had the lowest radiographic score (48%), because of the untreated graft fracture. The highest radiographic scores were in cases 1 and 3 (90% and 93%), both intercalary grafts reviewed after 36 and 26 years respectively.

Infection has been described as the worst complication of bone allografts (Lord et al 1988), but occurred in none of these patients. One patient (case 5), who had an osteoarticular allograft after resection of an aggressive type 3 giant-cell tumour, developed a valgus deformity of the knee due to loss of the medial soft tissues from tumour invasion. A high tibia osteotomy was performed, and

Table III. Radiographic evaluation of six patients treated by massive bone allografts according to the MSTS rating system

<table>
<thead>
<tr>
<th>Case</th>
<th>Union</th>
<th>Contour of graft</th>
<th>Density</th>
<th>Diameter</th>
<th>Stability</th>
<th>Change†</th>
<th>MSTS rating‡ (per cent)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Proximal*</td>
<td>Distal*</td>
<td>Fixation†</td>
<td>Host</td>
<td>Host</td>
<td>–</td>
<td>–</td>
<td>90</td>
</tr>
<tr>
<td>1</td>
<td>+</td>
<td>Cortical erosions</td>
<td>No change</td>
<td>Matches host</td>
<td>Matches host</td>
<td>–</td>
<td>77</td>
</tr>
<tr>
<td>2</td>
<td>+</td>
<td>Cortical erosions</td>
<td>No change</td>
<td>Matches host</td>
<td>Matches host</td>
<td>Matches 4 mm narrowing</td>
<td>93</td>
</tr>
<tr>
<td>3</td>
<td>+</td>
<td>Cortical erosions</td>
<td>No change</td>
<td>Matches host</td>
<td>Matches host</td>
<td>–</td>
<td>74</td>
</tr>
<tr>
<td>4</td>
<td>+</td>
<td>Severe resorption Fracture</td>
<td>No change</td>
<td>&lt; Host</td>
<td>Matches host</td>
<td>Dislocated Subchondral fragmentation</td>
<td>74</td>
</tr>
<tr>
<td>5</td>
<td>+</td>
<td>Mild resorption Cortical erosions</td>
<td>No change</td>
<td>&lt; Host</td>
<td>Matches host</td>
<td>Matches 2 mm narrowing</td>
<td>66</td>
</tr>
<tr>
<td>6</td>
<td>+</td>
<td>Cortical loss Mild resorption</td>
<td>No change</td>
<td>&lt; Host</td>
<td>&lt; diameter</td>
<td>–</td>
<td>–</td>
</tr>
</tbody>
</table>

* + = mature callus; line of osteotomy not visible
† refers to state of screws or plates used to fix the graft
‡ compared with contralateral joint
§ see text
the functional and radiographic scores at 22 years later were 93% and 74%, respectively.

Four of the allografts had suffered fractures in the early years after transplantation. The good final outcome in three of them shows that this complication can be effectively treated, and that good function can be restored, as reported by other authors (Berrey et al. 1990).

Bone allografts were first used mainly for reconstructions after excision of tumours, and often in patients with a poor expectancy for life and for function (Salama 1983; Solomon 1991). Recently, however, the use of allografts has been extended to include reconstructive procedures after failed joint arthroplasty and after severe traumatic bone loss (Allan et al. 1989), sometimes in young patients with a good life expectancy. In such patients, allografts need to be durable and this small series of patients shows that a massive femoral allograft can continue to function well even after more than 30 years.

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


