A technique for enhancing union of allograft to host bone

From the Prince of Wales Hospital, Hong Kong

The aim of limb-salvage surgery in malignant bone tumours in children is to restore function and eradicate local disease with as little morbidity as possible. Allografts are associated with a high rate of complications, particularly malunion at the allograft-host junction. We describe a simple technique which enhances union of allograft to host bone taking advantage of the discrepancy in size between the adult allograft and the child’s bone. This involves lifting a flap of periosteum before resection from the host bone, which is then telescoped into the allograft medullary canal, which may require internal burring or splitting, for a distance of 1.5 to 2 cm and covering the bone junction with the periosteal flap. This is more stable than conventional end-to-end opposition. For each centimetre of telescoping the surface area available for bony union is increased more than three times. The periosteal flap also augments union. Additional surface fixation with a plate and screws is not necessary.

We have used this technique in nine children, in eight of whom there was complete union at a mean of 16 weeks. Delayed union, associated with generalised limb osteoporosis, occurred in one. Early mobilisation, with weight-bearing by three weeks, was possible. There was only one fracture of the allograft.

The standard treatment of malignant bone tumours in children is by wide local excision followed by one of several reconstructive procedures. Metal prostheses have been used for massive segmental skeletal reconstruction for several decades. Their use in children, however, has not been universally accepted because of mechanical and other complications. Diaphyseal intercalary resection with allograft reconstruction is increasingly used as a means of preserving joint function. Some authors have reported a low rate of complications, but others have found a rate from 16% to 40%, particularly because of nonunion at the host-allograft junction.

Paediatric allografts are rarely used for weight-bearing reconstruction since the unfused physeal plate is a potential source of mechanical failure. Bone allografts are usually taken from skeletally mature donors and are often appreciably larger than the recipient child’s bone. The discrepancy in size after segmental diaphyseal resection hinders the use of surface fixation devices such as plates, which may require bending to ensure good surface contact.

We were able to use this size discrepancy to our advantage in a group of children who had segmental diaphyseal resection and allograft reconstruction. The larger diameter allograft was telescoped over the host bone and the junction covered with a periosteal flap. The aim was to improve both the initial stability and the potential for early allograft-host bony union compared with conventional end-to-end opposition. Stability was reinforced by intramedullary splintage.

Patients and Methods

We performed segmental diaphyseal resection and telescoped allograft reconstruction in nine patients (four boys, five girls) aged from 7 to 12 years who had osteogenic sarcoma of the femur or the tibia (Table I). After staging of the tumour which included radiography, MRI, bone scintigraphy, thoracic CT and biopsy, all patients received preoperative chemotherapy followed by resection of the growth to an extent based on the preoperative MRI findings. We reconstructed the skeletal defect using adult allograft bone obtained from the Musculoskeletal Tissue Bank of the Chinese University of Hong Kong.

Operative technique. Before removal of the tumour, the periosteum 2 to 3 cm distal to the level of bone resection was elevated as a flap (Fig. 1a). After excision, the intercalated defect was measured using the resected specimen as
a guide. An appropriate length of allograft was prepared with allowance for telescoping. In seven patients, the diaphysis of the host bone was telescoped into the allograft for 1.5 to 2 cm (Fig. 1b). In three of these patients internal burring of the allograft and in two splitting of the allograft down three sides in a cloverleaf manner was needed to allow telescoping over the host bone (Fig. 2a). We used a cerclage wire to secure the split allograft (Fig. 2b). In all nine patients the periosteal flap was positioned over the site of union of the host and allograft bone. Internal splintage was provided by an intramedullary nail in seven patients and a fibular autograft in two (Fig. 3). At the metaphyseal end, the width of the allograft was trimmed to match that of the host in both osteoarticular and intercalary resections.

Table 1. Details of the nine children and the type of resection-reconstruction, follow-up and eventual outcome

<table>
<thead>
<tr>
<th>Case</th>
<th>Gender</th>
<th>Age (yr)</th>
<th>Site</th>
<th>Stage</th>
<th>Type of reconstruction</th>
<th>Time to union (wk)</th>
<th>Complication</th>
<th>Follow-up (mth)</th>
<th>Function</th>
<th>Status</th>
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<td>II-B</td>
<td>Intercalary</td>
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<td>Fracture</td>
<td>30</td>
<td>Excellent</td>
<td>No evidence of disease</td>
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<td>Osteoarticular</td>
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<td>20</td>
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<td>Died from disease</td>
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<td>Local recurrence</td>
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<td>16</td>
<td>None</td>
<td>11</td>
<td>Excellent</td>
<td>Died from complications</td>
</tr>
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<td>Allo-arthrodesis</td>
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Fig. 1
Diagrams showing a) the elevated periosteal flap of native bone and b) the telescoping of host bone into the allograft and covering of the junction by periosteum.

Fig. 2
Diagrams showing a) the cleavage of the allograft to accommodate host bone and b) the securing of the allograft-host junction with cerclage wires.

Fig. 3
Lateral radiograph of an allograft-tibial bone junction and intramedullary splintage with fibular autograft. Bony union is visible on both the endosteal and periosteal margins of the allograft.
Metaphyseal stabilisation was secured by wire loops and Kirschner wires. The stability of the reconstruction was tested clinically before closure of the wound. The patients were allowed to mobilise the leg with the aid of a hinged brace in the first week after operation within the limits of comfort. Partial weight-bearing was allowed by the third postoperative week. All patients were able to bear weight fully in the eighth postoperative week.

Results

The postoperative clinical progress of the patients was closely monitored and regular radiographs were taken to assess the state of union at the host-allograft junction. The median follow-up was 25.5 months (mean 25). All patients received postoperative chemotherapy for 16 weeks which did not have an adverse effect on callus formation or bony union. Early periosteal callus was noticeable at six weeks in eight of the nine patients. This progressively enveloped the host-allograft junction and corresponded well to the extent of coverage achieved by the periosteal flap (Fig. 4). Bony union progressed simultaneously at the endosteal surface. There was progressive obliteration of the allograft endosteal and host-bone periosteal interface. Union of the allograft-host junction was deemed complete when this was no longer visible radiologically. The mean time to union was 15 weeks (Table I). Protective external braces were discarded when union was solid and joint movement satisfactory. No patient had nonunion.

In one patient the periosteal callus was poor in association with osteoporosis of the adjacent host bone (Fig. 5). There were no allograft failures. Fracture of the allograft occurred in one patient at 20 months, and was treated by a vascularised fibular graft (Table I).

One year after resection, clinical function was assessed using the grading system developed by the Musculoskeletal Tumour Society. Function was excellent in six and fair in three patients (Table I).

Discussion

The stability of the host-allograft bone junction is of great importance for achieving rapid bony union. The reported rates of failure for host-allograft bony union suggest that conventional methods of osteosynthesis which are so successful in the treatment of fractures may not be entirely suitable for allograft stabilisation. A multicentre study involving 113 cases reported a 57% incidence of delayed union after intercalary allograft reconstruction or arthrodesis. In the same study, fractures were seen in 16% of allografts in which a plate was used, and in 12.5% of those with an intramedullary nail.

Other studies have shown that often many years after implantation, an allograft will remain as an inert piece of bone with very little or no remodelling. It is not surprising that plates and screws inserted in a tissue that is avascular and has no remodelling capacity may result in fatigue failure of the allograft through stress risers beyond the plate or through the screw holes. Multivariate analysis of fractures of large segment allograft showed significant corre-
lation with the use of screws and plates. Immune-related resorption of the margin of the allograft may further jeopardise the stability of the host-allograft junction.

Histological studies have shown that bone formation at the host-allograft junction is initiated by enveloping callus from the host periosteum. Surface plates interfere mechanically with this process, which may explain the unsatisfactory results associated with their use. Telescoping the host bone into the allograft results in a more secure method of reconstruction than conventional end-to-end opposition. The contact area of the bone surface between host and allograft is increased more than threefold for every centimetre of telescoped length (Fig. 6). This encourages better union over a longer segment than the conventional spot-weld type of annealing seen with end-to-end opposition. Additional surface metal is rarely required. This method of reconstruction is sufficiently stable to allow early activity at one week and partial weight-bearing at three weeks after operation.

Telescoping opposing bone ends, in a similar fashion to that described, has been used previously to good effect in the treatment of difficult fractures. The contact surface area of the host and allograft may also be increased by using a Z-shaped interlocking to oppose both bone ends. This arrangement does not, however, confer any additional stability which must be achieved by metal implants.

The aim of limb-salvage surgery in children with a malignant growth is to restore function and eradicate local disease with as little morbidity as possible. Allografts are a useful means of retaining limb function despite a high rate of complications. This simple technique of telescoping the host bone into the allograft has allowed us to avoid some of the problems of host-allograft union with the minimal use of metal implants.

Fig. 5
Lateral radiograph of an allograft-femoral bone junction. Poor progression of bony union is seen at a) two months, b) four months, c) ten months and d) 15 months after reconstruction.

Fig. 6
Diagrams showing how telescoping increases the surface area available for bony union compared with conventional end-to-end oppositional alignment.

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\text{Area of Contact in } A = \Pi dx + \frac{1}{2} \Pi d^2
\]

\[
\text{Area of Contact in } B = \frac{1}{2} \Pi d^2
\]

where \(d\) = diameter of host bone and \(x\) = length of telescoped portion. The difference is 3.142 times the diameter for every centimetre of telescoping (\(\Pi = 3.142\)).

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


