The use of structural proximal femoral allografts in complex revision hip arthroplasty

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Between April 1992 and November 1998 we used 34 massive proximal femoral allografts for femoral reconstruction at revision hip arthroplasty. Seven patients have died and two have been lost to follow-up. There were thus 25 grafts in 24 patients for review. The mean follow-up was 53 months (16 to 101). By the time of the review two patients had undergone a further revision for failure of the allograft. Another had required secondary plating and grafting at the graft-host junction for symptomatic nonunion. One had recurrence of deep sepsis and was being managed conservatively.

Trochanteric union was considered to have occurred radiologically in 16 of the 25 grafts and union at the host-graft junction in 20. Resorption of the allograft was significant in only two hips. We recommend this technique in cases in which femoral bone loss has been catastrophic.

Extensive bone loss is a particular problem in revision hip surgery. The increasing use of total hip replacement in younger patients will create a need for multiple revisions in which subsequent bone loss is more likely. Patients’ expectations have also advanced so that non-operative solutions to bone loss, with their consequent limitation of mobility for the patient, are less acceptable. Advances in technology and a broader experience of massive bone loss around a hip replacement have led to a greater willingness to tackle this complex issue.1-4

There are a number of options currently available for the management of extensive proximal femoral bone loss. Bypass of the defect with an uncemented stem which is fixed distally with either a press-fit or distal locking screws is widely used.5 Massive tumour-type prostheses have also been used in younger patients by oncological surgeons. Their use in revision arthroplasty is expanding. When bone replacement is an issue, particularly in younger patients, impaction allografting within a containing metal mesh is becoming popular4,6 although some bone defects remain beyond this technique. The use of massive cadaver allograft has been pursued by a number of centres, particularly in the USA and Canada,1,2 but has been limited in the UK. There is no large published series originating from the UK.

The senior author (IS) has wide experience of the use of massive allograft both for femoral and acetabular reconstruction. We now review our experience over eight years of the use of massive allograft for extensive bone loss around the proximal femur.

Materials and Methods

We carried out a retrospective review of all patients in whom a proximal femoral allograft (PFA) had been used between April 1992 and November 1998. This period was chosen in order to ensure a reasonable minimum follow-up. During this time 34 PFAs had been implanted in 33 patients. Seven had died by the time of the review and two had been lost to follow-up. Twenty-five allografts in 24 patients were thus available for review.

There were ten men and 14 women. One of the men had undergone bilateral PFAs. Their mean age was 64 years (28 to 86) and the mean follow-up was 53 months (16 to 101). Eight patients had significant intercurrent illness; six had rheumatoid arthritis, one was diabetic and one had an isolated metastasis from a renal carcinoma.

Of the seven patients who had died, two deaths occurred within 30 days of the index procedure. The remaining five patients died from unrelated causes, although each had had a successful allograft/host-implant composite at a mean of 17 months after the index revision. No further information on this group of deceased patients was included in the subsequent study.
All the allografts were cadaver grafts harvested locally from multiorgan donors. Consent had been obtained from both the deceased and their next of kin. All donors had undergone routine screening for transmissible diseases including HIV types I and II and hepatitis B and C. The grafts were harvested under sterile conditions although all underwent secondary sterilisation using an industrial radiation source. The grafts were then stored at -70°C.

Each patient had undergone a mean of four earlier procedures to the index hip. All except one had had at least one previous arthroplasty to the index hip. Seven patients had had two or more revisions.

The reason for revision was aseptic loosening of the existing arthroplasty (14 hips), deep infection (five), periprosthetic fracture (four), recurrent dislocation (one) and metastatic carcinoma (one). The patients with pre-existing sepsis were operated on as part of a two-stage exchange. In all cases it was felt that standard revision techniques were inadequate for the degree of proximal femoral bone loss (Fig. 1). The defects were classified using the Paprosky femoral defect classification. There were 15 type-3B proximal femora, four of which were associated with a fracture. The remaining ten proximal femora were type 3C.

All operations were performed using a trochanteric osteotomy. The remaining host bone was retained in all cases, being split longitudinally and eventually closed around the final allograft-implant composite. A step-cut osteotomy at the graft-host junction was used in each case (Fig. 2). Morcellised autograft, when available, was packed around the graft-host junction. When no autograft was available morcellised allograft was used from the head of the PFA which was milled with a mechanical, hand-powered bone mill. When larger quantities of bone graft were required additional bone-banked femoral heads were used. The host-graft junction was augmented in all cases with a single or double 18-gauge cerclage wire. Further augmentation of this site with structural strut allograft was necessary in six cases.

The bearing surfaces which were used were cobalt-chrome on polyethylene with a 28 mm femoral head. All except one of the acetabular components was inserted with cement. Three hips had sufficient acetabular bone loss to require bulk allografting. Two acetabula required impacted allograft augmented by a support ring and a further 11 needed acetabular impaction allografting with mesh augmentation (Fig. 3).

In four hips acetabular reconstruction required only a small quantity of impacted allograft alone and in a further five no accessory augmentation of the acetabulum was needed.

In all cases the implant was cemented into the PFA with Palacos-R acrylic bone cement (Schering-Plough Ltd, Welwyn Garden City, UK) (Fig. 4). In the selection of the stem there was always a minimum bypass of 5 cm of the stem.
graft-host junction. In 18 cases (72%) a cemented, collared stem (Johnson & Johnson, Montreal, Canada) was used. In two an S-Rom (Depuy/Johnson and Johnson, Leeds, UK) stem and in the five most recent cases a Huckstep stem (B. Brown Medical Ltd, Sheffield, UK) were inserted. One case (Fig. 4) required a polished, tapered stem (Howmedica, Exeter, UK), although this was the only case in which cement was used distal to the host-allograft junction. In two cases in which a Huckstep stem had been used locking screws were inserted through the distal end of the implant into the femoral host bone. The other implants relied upon a distal press-fit for their initial fixation.

The initial stability was augmented in all cases by the step-cut osteotomy and cerclage wire. All constructs relied upon graft-host union for longer-term stability. Post-operatively, all patients were partially weight-bearing for three months in order to allow a degree of host-allograft union before full weight-bearing was permitted.

The graft stem construct was formed in the operating theatre on a sterile trolley. The graft was held in a vice and reamed sequentially with power reamers in order to accept the selected stem. A cement mantle of at least 2 mm was sought. The graft was then washed in order to remove any bony debris.

Cement pressurisation was achieved by thumb occlusion of the distal end of the graft during the insertion of cement. This was mixed in a closed-vacuum system, and inserted with a cement gun in order to maximise pressurisation.

Secondary pressurisation also occurred during insertion of the stem into the graft construct. Excess cement was removed from the exposed distal cut surface of the PFA in order to prevent it from being interposed between the PFA and the host bone. This part of the procedure was also performed away from the host, on the operating-theatre trolley. Trochanteric reattachment was achieved with either a cable-grip system or cruciate wiring with 18-gauge stainless-steel wire.

The notes and radiographs of the 24 patients were obtained. Each patient completed an Oxford hip score questionnaire. Fifteen were reviewed clinically. The remaining nine completed a Oxford hip score by post and their follow-up status taken as the findings at their most recent clinic appointment.

The immediate post-operative anteroposterior and lateral radiographs of the operated hip were available for each patient. Radiographic assessment was performed using the most recent anteroposterior and lateral views.

The trochanter was considered to be united on the anteroposterior radiograph if trabecular bridging was seen. If there was proximal migration of the greater trochanter of less than 1 cm from its original bed, the union was considered to be fibrous. If the trochanteric migration was greater than 1 cm this was considered to be ununited.

At the graft-host junction radiological union was regarded as complete if no residual radiolucent line could be seen on the most recent anteroposterior or lateral radio-

Fig. 3
Radiograph showing the support ring and allograft acetabular augmentation.

Fig. 4a
Fig. 4b
Photographs showing the cementation of the stem-allograft composite.
graph. When there was only partial loss of the junctional radiolucent line, spot welding or partial union was considered to have taken place (Fig. 5). If there had been no reduction in the degree of radiolucency at the graft-host junction over the lifespan of the implant this was regarded as being a nonunion or an asymptomatic fibrous union.

Resorption of the allograft was only recorded when it extended the full breadth (100%) of that allograft's original cortical thickness as seen on the anteroposterior radiograph. This was then related to Gruen zones 1 to 7. The lateral radiographs were also assessed for osteolysis using the same criteria.

The outcome and complications were recorded as either clinical or radiological. All failed hips which required revision underwent an aspiration of the hip in order to exclude sepsis. This information, combined with clinical data and measurement of the ESR and the level of C-reactive protein determined whether the failure was considered to be aseptic or septic.

Results

The mean Oxford hip score was 34 (13 to 57) at the time of this review. There was one isolated acetabular revision and two allograft revisions. One patient developed recurrence of sepsis in the index revision but is currently being managed non-operatively with antibiotic suppression.

Of the two allografts which had required revision, one had been performed after 79 months for a combination of aseptic femoral and acetabular failure. The cemented acetabular component was loose and symptomatic. There was also nonunion of the trochanter and, more significantly, of the graft-host junction. Even in this case resorption of allograft was seen only in Gruen zones 3 and 7 before the rerevision which required the implantation of a further massive proximal femoral allograft. The second failure was for late sepsis at 48 months after the index revision. This followed an earlier isolated acetabular revision for aseptic loosening after only 18 months. The infection was treated by a two-stage technique and a further massive PFA was implanted. Neither of these two re-implantations formed part of this review as in both the follow-up was less than 12 months.

One patient developed symptomatic nonunion of the graft-host junction. This presented as persistent thigh pain and required an early revision of the graft-host junction. The junction was explored and augmented with iliac autograft and a plate and cable construct. This resolved the symptoms although graft-host union is currently being assessed.

Two patients have had their trochanteric wires removed because of trochanteric irritation.

Bony resorption of the allograft was only significant in two patients. Neither has required revision at 37 and 81 months. There was 100% cortical resorption in three (2, 5 and 6) and four (2, 5, 6 and 7) zones, respectively. Radiographs of bone resorption at 81 months are shown in
supported the technique around the knee\textsuperscript{14} and acetabulum\textsuperscript{15,16} However, its use remains limited to specific centres, particularly in the UK. Our series represents the largest in the UK of which we are aware.

When compared with other large series from North America\textsuperscript{1,2} ours compares well, although it does not have long-term follow-up. Our operative technique mirrors that previously published by Gross et al\textsuperscript{17} The allografts were irradiated before the storage and implantation, unlike the series of Haddad et al\textsuperscript{2} in which non-irradiated bone was used. This may have a bearing on bone resorption and the immune response. It has also been suggested that stress shielding and disuse osteopenia may have a part to play in bone resorption, which can be seen in all structural allografts to varying degrees. Haddad et al\textsuperscript{2} relied on cementation of the component into both graft and host bone. This is unlike our technique or that of Gross et al\textsuperscript{17} in which the initial stability relies upon the step-cut osteotomy and a press-fit distal stem. It is an assumption that this distal press-fit will mechanically load the graft and prevent resorption. Our low rate of significant resorption (2 of 25 grafts) compared very favourably with the resorption figures at five and three years of these other studies. We preserved the remaining host proximal femur in all cases, primarily to maximise the local blood supply and to enhance stability through the remaining soft-tissue envelope.

It is well recognised that muscle and tendon attachments alone significantly load bone and may have contributed to our low rate of early resorption. The importance of using the allograft as a load-sharing structure and not as an isolated load-bearing device cannot be overemphasised. Earlier studies\textsuperscript{18} have reported post-operative periprosthetic fractures when the allograft was expected to act solely as a structural support.

There are alternatives. These include tumour replacement components\textsuperscript{19,20} and impaction grafting techniques. The advantage of the use of a massive allograft when compared with impaction techniques lies in the inherent initial stability of the massive allograft construct. Tumour replacement components are expensive, particularly if modularity is used, and there is no prospect of the soft tissue becoming structurally adherent to the metalwork. One comparative study\textsuperscript{21} showed that graft composites are more likely to survive in the long-term than mega-prostheses.

Tumour replacement components and custom prostheses offer an alternative. They may be cemented or uncemented and, if modularity is used, both stability and leg length can be optimised. Much of the evidence for their use comes from limb-salvage surgery for musculoskeletal tumours.\textsuperscript{22} Although young and active, these patients have a limited lifespan over which the implant has to perform. In revision arthroplasty after an initial diagnosis of arthritis, life expectancy is often normal. Issues of bone stock and reversion must therefore be considered.

Restoration of proximal femoral bone stock remains one of the goals of revision, particularly in the younger age groups. Massive circumferential allograft is one of the techniques available for this purpose. Other studies\textsuperscript{3,7,23,24} have successfully used structural onlay grafts in order to restore bone stock, but large circumferential defects are often beyond this technique. Although the restoration of bone stock remains the object of such surgery we had to discard.

**Table I.** Rate of junctional union in the 25 hips

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<th>Review period (mths)</th>
<th>Junctional union</th>
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<td>17</td>
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<td>19</td>
<td>Nonunion</td>
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<td>United</td>
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<td>Nonunion</td>
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<td>35</td>
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the graft in the two cases which required revision. In one this was because of late sepsis and in the other several factors were to blame including graft-host nonunion, implant-graft separation and trochanteric nonunion.

A further potential advantage of allograft over metal augmentation for bone loss is retention of the soft-tissue attachments around the hip. Although this is only likely to be in the form of scar tissue it will still confer extra stability to the reconstruction. Rates of dislocation as high as 35% have been reported with megaprostheses.21 In the distal femur in which custom prostheses are more commonly used in tumour surgery, failure of the implant occurred in 32% of cases at ten years.23 This is not always the case for the proximal femur in which a survivorship of over 70% at ten years has been reported,20 albeit with a high rate of dislocation. There were no dislocations in our series at the time of our review.

Some authors advocate the use of large uncemented titanium implants with augmentation of bone stock by structural onlay allograft.24 Others have also supported the use of similar types of uncemented proximal femoral replacement.20

A custom component does not address the issue of bone restoration, but does avoid the risk of transmission of disease associated with allograft bone. Hepatitis B and C and HIV transmission are of considerable concern. The dangers of prion transmission and the human form of CJD remain an important issue although the true level of risk remains unknown.

Bone banking is thus one of the major issues which currently surrounds bone restoration with allograft. Bone substitutes offer a possible solution although they remain largely untested in the field of revision arthroplasty.27,28

Impaction grafting has recently received much attention because of the bone restoration properties of the technique.29 Some of the earliest published work was undertaken by Gie et al26 who still perform and develop the technique. Histological studies of impacted allograft have shown that allograft particles remain in a fibrous bed for up to eight years after the index operation.31,32 Radiographic studies of this technique suggest neovascularisation and formation of new bone in the proximal femur.33 Excessive migration of the stem and periosteal fracture remain a concern, although there is evidence that this may be technique-related.34-36 There are encouraging reports of good early- and medium-term results with impaction grafting in the proximal femur but this experience is not universal.34,35

No technique for massive circumferential bone loss around the proximal femur provides a perfect or risk-free solution to the patient. However, in our hands, and with the support of a well-run bone bank, the use of structural proximal femoral allografts offers a satisfactory medium-term result for this group of patients.

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


