Structural proximal femoral allografts for failed total hip replacements

A MINIMUM REVIEW OF FIVE YEARS

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There are few medium- and long-term data on the outcome of the use of proximal femoral structural allografts in revision hip arthroplasty. This is a study of a consecutive series of 40 proximal femoral allografts performed for failed total hip replacements using the same technique with a minimum follow-up of five years (mean 8.8 years; range 5 to 11.5 years). In all cases the stem was cemented into both the allograft and the host femur. The proximal femur of the host was resected in 37 cases.

There were four early revisions (10%), two for infection, one for nonunion of the allograft-host junction, and one for allograft resorption noted at the time of revision of a failed acetabular reconstruction. Junctional nonunion was seen in three patients (8%), two of whom were managed successfully by bone grafting, and bone grafting and plating respectively. Instability was observed in four (10%). Trochanteric nonunion was seen in 18 patients (46%) and trochanteric escape in ten of these (27%). The mean Harris hip score improved from 39 to 79. Severe resorption involving the full thickness of the allograft was seen in seven patients (17.5%). This progressed rapidly and silently, but has yet to cause failure of any of the reconstructions.

Profound resorption of the allograft may be related to a combination of factors, including a slow form of immune rejection, stress shielding and resorption due to mechanical disuse with solid cemented distal fixation, and the absence of any masking or protective effect which may be provided by the retention of the bivalved host bone as a vascularised onlay autograft. Although continued surveillance is warranted, the very good medium-term clinical results justify the continued use of structural allografts for failed total hip replacements with severe loss of proximal femoral bone.

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Severe loss of femoral bone around a failed total hip prosthesis increasingly makes conventional revision techniques difficult or impossible.\(^1\)\(\text{-}\)\(^7\) In such cases, one option is to use proximal femoral allograft-prosthetic composites.\(^1\)\(\text{-}\)\(^4\),\(^7\)\(\text{-}\)\(^15\) These have become a major part of the armamentarium of reconstructive surgeons, but their place in revision arthroplasty of the hip remains controversial. The perceived advantages over the use of customised endoprostheses include better soft-tissue attachment and reduced loss of distal bone, but, in spite of a number of promising reports from specialist units, there are few long-term reviews.\(^16\)

Most published studies involve small numbers of patients and a relatively short follow-up.\(^10\),\(^12\),\(^14\),\(^17\),\(^18\) The notable exception is the extensive experience of Gross and Hutchison\(^4\) which represents both the longest-term and the most successful results. They reviewed 200 circumferential allografts longer than 5 cm. Using an increase in hip score of 20 points, a stable implant and no further surgery to the allograft as a definition of success, they were able to report a rate of success of 85% (111 of 130 patients) at a mean follow-up of 4.8 years (minimum 2 years). In a further study at a minimum of five years, they reported a rate of success of 85% (55 of 65 cases) at a mean follow-up of nine years. However, there are still concerns since the procedures are technically demanding and expensive. There is a potential for transmission of disease.\(^19\)\(\text{-}\)\(^22\) The biological drawbacks of allograft bone include the risks of nonunion, and fracture and resorption of the graft. Moreover, it has not been proved that loosening of an alloimplant is less troublesome than loosening of a proximal femoral replacement.

The issue is further complicated by the great variability within studies reporting the use of structural femoral allografts. The types of allograft used, their preoperative processing and their operative preparation can differ markedly between centres. A wide range of prostheses has been
employed with no uniformity of methods of fixation either within the allograft or within the host femur. There are also confounding factors such as the degree of immunological matching between the graft and the host, the soft-tissue cover available, the vascularity of the host bed and the amount of dissection and soft-tissue stripping required in each case. Our aim was to undertake a minimum review of five years on 40 consecutive, fully cemented, proximal femoral allografts carried out for failed total hip replacements.

Patients and Methods

There were 18 men and 22 women in the series with a mean age at the time of the index revision of 58 years (29 to 83). The right hip was involved in 23 and the left hip in 17. They were followed up for a minimum of five years (mean 8.8 years; range 5 to 11.5) and clinical and radiological data were available for this period for all patients. The final review was carried out by an independent observer (FSH). Five of the patients died from unrelated causes, and one was lost to follow-up.

The indication for allograft reconstruction was aseptic failure of total hip replacements with severe bone loss in 32 patients and infection in eight. There were 13 segmental femoral defects and 27 combined cavitary and segmental deficiencies. In all cases the bone loss was severe enough to prevent satisfactory press-fit fixation with a standard revision prosthesis. There were 32 acetabular reconstructions, in 17 of which morsellised allograft bone was used. A bipolar head was used in eight. In the presence of sepsis, the proximal femoral allograft revision was the second stage of a two-stage reconstruction using an interval spacer. These patients had previously undergone a mean of 2.6 procedures (1 to 6) on the same hip.

None of the allografts was irradiated, and in all cases the stem was cemented into both the allograft and the host femur. At the time of the reconstruction, the host bone was discarded in all except three cases. A step-cut osteotomy at the host allograft junction was used in 12 patients and a transverse osteotomy in 28. The greater trochanter was fixed to the allograft with a cable grip in 35 patients, with wire and mesh in three, and with staples in one. In one other patient the trochanter could not be brought down to the allograft, and soft-tissue attachment of the abductors was undertaken.

All the patients completed a questionnaire regarding the outcome and their satisfaction with the procedure. A WOMAC (Western Ontario and McMaster Osteoarthritis Index) scale was also completed, although the corresponding preoperative data were not available. Outcome parameters included a visual analogue scale of pain and satisfaction, scored from 0 to 10. A Harris hip score was completed for comparison with the preoperative scores.

Serial radiographs were assessed with particular emphasis on junctional and trochanteric union, and on the presence of any allograft resorption. Trochanteric escape was defined as a nonunion with migration of the greater trochanter of more than 1 cm. The allograft was divided into zones similar to those of Gruen, McNeice and Amstutz in total hip arthroplasty. Zones 1 and 4 were excluded because of the absence of an allograft trochanter (zone 1) and because of the allograft-host junction (zone 4). In each zone, bone resorption was graded as minimal or absent, up to 50% of the thickness of the cortex, between 50% and full thickness, or full thickness down to the cement mantle. Any resorption in relation to trochanteric wires or cables in zone 7 was also noted but was not included in the grading of the resorption. In each case, note was taken of whether the resorption was endosteal or periosteal. After a zonal analysis of the allografts on serial radiographs, allograft resorption was graded as follows: mild, being less than 50% of allograft thickness in one or two zones; moderate, being less than 50% of the thickness in more than two zones, or greater than 50% thickness but not full thickness in one or two zones; or severe, being full thickness in any zone or greater than 50% thickness in more than two zones.

Results

Clinical. The Harris hip score improved from a mean of 39 (15 to 60) before revision surgery, to a mean of 79 (26 to 96) at the latest review. There was an improvement of more than 40 points in 24 patients (60%), and of more than 20 points in 36 patients (90%) (Table I). We could not identify any relationship between the age of the patients or the severity of the preoperative bone loss, and the improvement in hip and pain scores. There was no significant restriction of movement, with over 75° of flexion in all the hips. The mean walking distance was eight blocks, and 33 of the 40 patients (83%) needed the support of a cane or less support at their latest review. The mean visual analogue scale (VAS) to pain was 4.9 (1 to 10), and the mean satisfaction VAS was 8.1 (2 to 10). The mean WOMAC scores at the latest review are summarised in Table II.

Although we do not have preoperative data for comparison, these correspond to moderate pain, moderate stiff-
nness, and only moderate difficulty with physical activity.

**Radiological**

*Union at the allograft-host junction.* This was ultimately achieved in 37 of the 40 allografts (Fig. 1). The three cases of nonunion included one which was successfully revised by a further allograft reconstruction. In the other two patients treatment was successful with plating and bone grafting in one and with bone graft alone in the other.

*Greater trochanteric union.* This occurred in 21 patients. Nonunion of the greater trochanter was seen in 18 of the 39 patients in whom the trochanter was fixed to the allograft (46%). Greater trochanteric escape was noted in ten of these (26%).

*Resorption.* This was graded as mild in nine patients, moderate in four and severe in seven. Moderate or severe resorption was therefore seen in 11 patients or 28% of the series (Figs 2 and 3). The resorption was always periosteal, and typically started within the first year, although there were not significant changes in the first six months after surgery. It progressed rapidly and silently but there was no failure of any of the reconstructions. It tailed off typically by three years, with only slow minor progression thereafter. The minor resorption seen was usually in relation to wires or cables. Overall, zones 2 and 3 were most commonly affected, particularly in cases in which the allograft had been thinned out at that level. In all seven cases of severe resorption, the host proximal femur had been discarded at the time of the reconstruction. As far as possible, we excluded infection as a cause of resorption. None of the severe resorptions was in previously infected cases. Serological studies on these patients including measurement of the ESR and levels of C-reactive protein did not suggest infection, and in three cases, sepsis was formally excluded by either aspiration (two cases), or specimen culture at the time of revision (one case).

**Complications** (Table III). Five failed acetabular reconstructions required revision. In one, a severely resorbed proximal femoral allograft was revised to an endoprosthesis. Histological examination of the resected specimen revealed long-standing osteoclastic resorption, but no evidence of infection. There were four full revisions. One fractured allograft was successfully revised to a further allograft, and three revisions to endoprostheses were undertaken for infection (two cases) and one for junctional nonunion. Four further interventions were also necessary to perform a bone graft of the junction and to remove symptomatic trochanteric cable grips. Figure 4 shows the survivorship curve for femoral revision for this cohort. Instability was seen in four patients, all of whom had trochanteric nonunion and three of whom had trochanteric escape.

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**Table III.** Local complications from the femoral allografts

<table>
<thead>
<tr>
<th>Complication</th>
<th>Number</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fracture</td>
<td>1</td>
<td>2.5</td>
</tr>
<tr>
<td>Infection</td>
<td>2</td>
<td>5.0</td>
</tr>
<tr>
<td>Junctional nonunion</td>
<td>3</td>
<td>7.5</td>
</tr>
<tr>
<td>Greater trochanter nonunion</td>
<td>18</td>
<td>45.0</td>
</tr>
<tr>
<td>Greater trochanter escape</td>
<td>10</td>
<td>25.0</td>
</tr>
<tr>
<td>Instability</td>
<td>4</td>
<td>10.0</td>
</tr>
</tbody>
</table>

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Figure 1a – Radiograph showing a loose total hip replacement with loss of femoral bone. Figure 1b – Early and late postoperative radiographs showing union at the transverse graft-host junction and trochanter. There is no resorption.
Radiographs showing a) a revision hip arthroplasty using a structural femoral allograft with a united step-cut junction and b) failure of the cable grip trochanteric fixation; cable filaments can be seen around the alloimplant in association with minor resorption.

Radiographs showing a) a proximal femoral allograft with a step-cut junction and b) unstable arthroplasty with trochanteric nonunion without escape; there is significant resorption of the allograft.
Discussion

Experience with this technique\textsuperscript{16} has resulted in some modifications. We now preserve any remaining host proximal femur, we do not cement distally, we use a step-cut junction, and we favour a trochanteric slide or an extended osteotomy over the classical trochanteric osteotomy. The cases described here are, nevertheless, worthy of further scrutiny. Because this group of patients has usually had multiple operations, the options available to the surgeon are limited. We were able to evaluate the medium-term effects of cemented distal fixation of the allografts, and to balance the medium-term outcome with the recognised complications of such reconstructions.

The implications of rigid distal fixation of the allograft are still unknown. The options for distal fixation have included distal cementing, a distal interference fit,\textsuperscript{9,10} interlocking fixation\textsuperscript{12} or a reliance on the stability of the junction using either a step-cut and wires\textsuperscript{2} or plates.\textsuperscript{25}

There has been a move away from cementing distally. Although cadaver biomechanical tests showed good stability with distal cementing,\textsuperscript{26-28} such a procedure may increase the risk of nonunion, and may not achieve good fixation because the distal femur had often been eburnated by the previous prosthesis. By not cementing into the distal host bone, the allograft also has a greater potential to share load once union has been achieved. Moreover, the distal femur can still support another reconstruction if necessary. Furthermore, should the alloimplant require removal for the management of infection, it would be more difficult and more destructive to the remaining bone stock if cemented distal fixation was used to secure the construct initially.

In some cases, however, when the junction is beyond the isthmus of the host femur, cementing may be necessary to provide primary distal stability. Although solid distal fixation may make a contribution in the multifactorial aetiology of resorption of the allograft, we have seen no medium-term ill-effects directly related to the use of fully cemented allografts. The rate of junctional nonunion of 7.5% corresponded closely to that reported using other techniques. Indeed, distal cementing may have overcome the potential problems created by a relatively unstable transverse allograft-host junction in some of our cases.

Our rate of infection of 5% is similar to the excellent results reported by Gross and co-workers.\textsuperscript{4,29} This confirms our observation,\textsuperscript{30} and that of others,\textsuperscript{31-33} that allograft reconstructions can safely be undertaken in two-stage revisions for infection. Dislocation was seen only in cases of trochanteric nonunion, and in all but one case in relation to trochanteric escape. A large proportion of the instability after proximal femoral reconstruction using structural allograft may be related to the lack of soft-tissue stabilisation, particularly when there is trochanteric migration. We now attempt to preserve the distal pull of vastus lateralis on the trochanteric fragment by performing a trochanteric slide, or by using an extended trochanteric osteotomy, which can be stabilised more securely. There was only one fracture of the allograft. By respecting the inert nature of allografts and not using plate and screws which would have created stress risers in the allograft, such fractures were avoided.\textsuperscript{34,35}

We saw a higher rate of resorption of the allograft than has been recognised previously. This has been noted before in some series\textsuperscript{15,17,29} but not in others.\textsuperscript{1-3,9,10,13} Even when resorption secondary to any mechanical effects of the wires or cables, or secondary to any remodelling effects at the transitional zones was excluded, moderate or severe resorption was still seen in 11 cases (28%). Although there have been no failures in relation to graft resorption, it remains a potential problem because of its initially rapid and progressive asymptomatic nature. A retrospective review such as this cannot explain the resorption, but allows us to generate hypotheses regarding its potential aetiology. It is most likely to be primarily an immunological problem of slow rejection. Allografts are known to be immunogenic,\textsuperscript{36-48} and as none of the allografts used was irradiated,

\begin{figure}[h]
\centering
\includegraphics[width=\textwidth]{figure4}
\caption{Kaplan-Meier survivorship curve with 95% confidence limits for revision of the proximal femoral allografts.}
\end{figure}

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they are therefore more likely to stimulate a host response. It is also possible that the distal cemented fixation led to stress shielding and resorption due to mechanical disuse. The discarded proximal host femur may also play a role. The residual host bone may have a physical and immunoprotective effect which was not present in our cases. Alternatively, any resorption in the presence of the host proximal femur may be more difficult to appreciate radiologically. We suggest that resorption of the allograft is a multifactorial problem. The external surface of the allograft is vulnerable to revascularisation and to immune attack and the impact of these factors is enhanced if the allograft is thin, if it is unloaded or if any potential masking or protective effects of the host are removed. Continued careful long-term follow-up is necessary to determine the clinical implications of resorption and to refine our technique further in order to avoid it.

In a very disabled group of patients, in whom the primary goal was to relieve pain and restore function, structural proximal femoral allografts were successfully used in complex cases for which there had been many previous interventions. Although there was a high rate of early reoperation, the medium-term survivorship was excellent, and the clinical outcome very satisfactory. Most of the patients improved dramatically. This was demonstrated both by the increase in hip scores and the high rate of satisfaction. Our mean eight-year improvement in hip scores was almost identical to the success rate of 85% reported by Gross and Hutchison. These improvements probably reflect a combination of the efficacy of the procedure and the very severe functional limitations experienced by patients who require allograft reconstructions. Our observation of marked resorption of the allograft in a significant proportion of the cases demands continued surveillance, but in the meantime our results justify the continued use of structural allografts for failed total hip replacements with loss of proximal femoral bone.

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References


