

Structural allografts for bone stock reconstruction in two-stage revision for infected total hip arthroplasty

Good outcome in 16 of 18 patients followed for 5–14 years

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Background The use of massive bone allografts in cases of revision of failed total hip arthroplasties (THAs) due to infection is controversial.

Patients and methods 18 patients presented with infection at the site of a THA and were treated with a two-stage protocol. In the first stage, the prosthesis was removed together with all necrotic tissues and cement material if present. A custom-made mold of Palacos R cement containing 1 g of gentamicin was then inserted in 17 of the 18 patients. Systemic antibiotics were used during the interval period. In the second stage, the patients had either acetabular or femoral reconstruction using bulk allograft bone.

Results Mean follow-up was 9 (5–14) years. 1 patient presented with recurrent infection and underwent a Girdlestone resection arthroplasty as definitive treatment. Another patient had a mechanical failure of the acetabular component, which was revised 10 years after the second stage of the reconstruction. The mean Harris Hip Score improved from 34 points preoperatively to 71 points at the last review. By our definition, 16/18 of the patients had a successful outcome.

Interpretation Our results support the use of massive allografts in staged reconstructions of infected THAs complicated by considerable bone loss.

It is estimated that 0.5–2% of all primary total hip arthroplasties (THAs) will be complicated by infection (Phillips et al. 2003). Two-stage revision procedures are considered to give the best outcome

(McDonald et al. 1989, Colyer and Capello 1994, Lieberman et al. 1994, Haddad et al. 2000). Extensive bone loss after the debridement and removal of foreign materials must be addressed at the time of reimplantation. Allograft bone is commonly used in revision hip arthroplasties without infection (Paprosky and Magnus 1994, Blackley et al. 2001), but its use in revisions for infection has been limited (Berry et al. 1991, Alexeeff et al. 1996, Wang and Chen 1997, Ilyas and Morgan 2001, English et al. 2002, Ammon and Stockley 2004). Since our original report on a series of 10 patients (Ilyas and Morgan 2001), we have continued to employ these techniques in cases of failed THA due to infection presenting with severe bone loss, and we now present our mid-term results.

Patients and methods

Between 1990 through 1999, we treated 18 patients (12 men) with a deep infection at the site of a THA according to a two-stage revision protocol, which included reconstruction with massive allografts. 1 patient died, but 5.5 years of follow-up data were available, which allowed inclusion of the patient in this study. The mean age at the time of the first stage of the revision was 66 (45–86) years. The initial diagnosis was primary osteoarthritis in 13 patients, traumatic osteoarthritis in 4, and ankylosing spondylitis in 1 patient. All patients had had the primary hip arthroplasty done elsewhere,

Table 1. Organisms cultured from the 18 patients

Organism	No. of patients
Coagulase-negative <i>Staphylococcus</i>	11
Methicillin-resistant <i>Staphylococcus aureus</i>	2
<i>Klebsiella</i>	1
Group D <i>Streptococcus</i>	1
<i>Bacillus cereus</i>	1
<i>Streptococcus pneumoniae</i>	1
Mixed flora	1

and they had had an average of 2 (1–9) operations performed on their hips after the primary THA. Infection at the site of the THA was diagnosed at an average of 6 (2–10) years after the primary hip arthroplasty. Clinically, all patients presented with pain. 4 also presented with fever, and 2 with draining sinuses. A preoperative core biopsy of the hip (Malhotra and Morgan 2004) was performed in 15 patients, and 12 had a positive bacterial culture.

The first stage included removal of all implanted devices, debridement of all necrotic tissues and membranes, and removal of all cement if present. At least 5 samples were taken for additional bacteriological studies. A custom Thompson prosthesis-like mold made of Palacos R cement containing 1 g of gentamicin (Heraeus Kulzer, Wehrheim, Germany) was then inserted in 17 of the 18 patients. In 1 patient, we used Palacos R cement beads containing 1 g of gentamicin because of technical difficulties in the preparation of the cement mold. We now prefer hand mixing of specific antibiotic in the cement spacer, chosen according to the infecting organism and its sensitivities (Joseph et al. 2003). If preoperative cultures are unavailable, we use Palacos R cement containing 1 g of gentamicin.

Parenteral antibiotics, chosen on the basis of the results of bacterial cultures of the intraoperative specimens (Table 1), were given for a period of 3–4 weeks. Subsequently, oral antibiotics were given for an average of 18 (1–31) weeks. During the time period between the first stage and the reconstruction stage, leucocyte counts, erythrocyte sedimentation rate (ESR), and C-reactive protein (CRP) levels were followed every 2 weeks. No patient had fever, and there was no evidence of infection or drainage of any wound. The interval between the removal of the failed prosthesis and

Table 2. Bone allograft material used in the 18 patients

Bone deficiency ^a Site/Type	No. of patients	Bone allograft	No. of grafts
Femoral			
Type 1	6	Anatomic specific proximal femoral allograft	6
Type 3	4	Anatomic specific proximal femoral allograft	4
		Cortical struts	2
Acetabular			
Type 1	2	Femoral head	2
Type 2	2	Femoral head	2
Type 3	5	Femoral head	3
		Acetabulum	1
		Distal femur	1

^a according to AAOS

implantation of a new implant together with bone allograft averaged 5 (1–8) months.

The second stage of the revision was undertaken on the basis of satisfactory resolution of clinical, laboratory and radiological evidence of sepsis. In 6 cases, Technetium-99 phosphate and Gallium-67 citrate bone scans were performed before the second stage of reconstruction, and did not indicate any evidence of current infection. During the second-stage operation, at least 5 samples were taken for bacteriological and histological examination, including Gram stain. Perioperative intravenous antibiotics were administered immediately after specimens were obtained, and this continued for 48 h.

The need for allograft bone was determined on the basis of the preoperative radiographic assessment and the findings during the second stage of the procedure. Bony deficiencies were classified according to the systems proposed by the American Academy of Orthopedic Surgeons Committee on the Hip (D'Antonio et al. 1989, 1993). The femoral deficiencies were classified as type 1 in 6 patients, and type 3 in 4 patients. The acetabular deficiencies were classified as type 1 in 2 patients, type 2 in 2, and type 3 in 5 patients. The bone allograft materials used are summarized in Table 2. Samples for bacteriological studies were taken from the allograft at the time of use. In all cases, the allograft bone was provided by the Queensland Bone Bank, which complies with all standards of the Musculoskeletal Council of the American

Association of Tissue Banks (Tomford and Mankin 1987), and the Code of Good Manufacturing of the Therapeutics and Goods Administration in Australia. All allografts were frozen and sterilized by gamma-irradiation (25 ± 5 kGy.). In the case of proximal femoral reconstruction, the implant was cemented only into the proximal femoral allograft using Palacos R cement, and the allo-implant composite was then inserted into the host femur in a cementless fashion. We used a step-cut osteotomy at the junction in order to achieve rotational stability and increased contact area, and the allograft was secured to the host femur using cables. The proximal femoral allografts had a mean length of 11 (5–19) cm. In the case of acetabular reconstruction, the host bone was reamed to achieve bleeding base. The allograft was countersunk under the iliac roof whenever possible in order to maximize contact area with host bone. In the case of rim deficiencies, when the allograft was screwed to the lateral ilium, the screws were placed parallel and in the direction of the joint reaction force to maximize compression. We used an uncemented hemispheric component when it was estimated that the allograft supported 40% or less of the acetabular component circumference. When it was estimated that the graft would support more than the 40% threshold, a support ring was preferred—combined with a cemented acetabular insert. The device linked the ilium above and the ischium below. The lateral section of the support ring overlaid the allograft on the lateral side of the ilium. This entire construct reduced the potential for shear and failure at the allograft-ilium interface.

We used the Harris Hip Score (HHS) for clinical evaluation. Routine anteroposterior and lateral radiographs were assessed for evidence of host-allograft union, bioprosthetic stability, graft resorption, fractures, and fragmentation. We defined success as a stable allograft-prosthesis composite with no clinical recurrence of infection, and the ability to increase HHS by more than 20 points.

Results

17 of the 18 patients had no evidence of recurrent infection during the 9 (5–14) years of follow-up. Definite deep wound infection developed in 1

patient, who presented with discharging sinuses 2 years after the index revision. This patient underwent a resection arthroplasty as definitive treatment. The organism grown from specimens taken during the last resection arthroplasty was the same as the initial infecting organism (coagulase-negative *Staphylococcus*).

Another patient presented with aseptic failure (mechanical loosening) of the acetabular component, which was re-revised 10 years after the reconstruction stage. Bacteriological cultures obtained during re-revision were negative.

The mean HHS improved from 34 (19–57) points preoperatively to 71 (46–97) points at the last review. All patients improved by more than 20 points. By our definition, 16/18 hips had a successful outcome. 1 of the 10 femoral reconstructions and 1 of the 9 acetabular reconstructions failed.

The radiographic analysis at the last review showed union of the allograft to host bone in all cases. Graft resorption was observed in 1 proximal femoral allograft. This was periosteal and was located in the area under cables used for fixation. We did not see any signs of definite loosening of any of the implants at the last radiographic review.

There were three complications: 1 patient had a fracture at the host step-cut after a fall 1 year after the second stage of the procedure. The allo-implant composite appeared stable and the fracture was stabilized using cortical strut allografts. 2 other patients had recurrent dislocations postoperatively. 1 of them was managed non-operatively, while the other had the acetabular liner changed to lock-capture-liner 6 years after the second stage of the procedure. At the operation, the anatomic-specific proximal femoral allograft was found to be united to host bone, with no signs of resorption. Bacteriological results from specimens taken during the procedure were negative.

Discussion

In a literature search, we found only two studies on massive allografts for bone stock reconstruction in cases of infected THA treated with staged protocols. In both studies, there were no cases of recurrent infection in 11 patients at a mean follow-up time of 4 years (Alexeeff et al. 1996), and in

10 patients after 5 years (Ilyas and Morgan 2001). English et al. (2002) used impaction grafting techniques and reported recurrent infection in 4 of 53 patients with a mean follow-up of 4 years, while the remaining studies have presented heterogeneous groups where morselized and bulk allografts were used, and reported recurrent infection rates between 9% and 14% after 4 years of follow-up (Berry et al. 1991, Wang and Chen 1997, Ammon and Stockley 2004). Higher recurrence rates have been reported with the passage of time (Nestor et al. 1994, Went et al. 1995). Even with a mean follow-up of 9 years and with some of the patients being followed for up to 14 years, only 1 of our 18 patients had a recurrent infection.

Several factors may be associated with an increased rate of reinfection after revision surgery for infected THA. McDonald et al. (1989) reported a fourfold increase in the incidence of recurrent infection when cement was retained after resection, while Nestor et al. (1994) could not find a statistically significant risk of reinfection in such cases. We, as other authors (Salvati et al. 1982), believe that thorough debridement of the wound and removal of all foreign materials—and especially all methylmethacrylate at the time of the first stage—are necessary for a successful reconstruction associated with a low rate of recurrence of infection.

Repeated debridement is advocated if there is evidence that infection has not been completely eradicated (Colyer and Capello 1994, Nestor et al. 1994), but we did not find this to be necessary in any of our patients.

In most reported series, the clinical outcome was closely related to the type of causative microorganism. Lower success rates have been reported when virulent bacteria (Gram-negative bacilli, group-D streptococci, enterococci, methicillin-resistant *Staphylococcus aureus*) (Buchholz et al. 1981, Salvati et al. 1982, Wang and Chen 1997), or polymicrobial flora (Sanzen et al. 1988) were involved. For such cases, McDonald et al. (1989) recommended microorganism-specific parenteral antibiotic therapy for at least 4 weeks, and an interval of at least 1 year between resection and re-implantation. 4 infections in our series were caused by virulent microorganisms (methicillin-resistant *Staphylococcus aureus*, *Klebsiella*, and

group-D *Streptococcus*), and one by mixed flora. All of these patients received appropriate parenteral antibiotic therapy for a period of 3–4 weeks, followed by oral antibiotic until the second stage of the revision. Re-implantation was performed 3–7 months after the resection stage. None of these cases presented with recurrence of infection; the only recurrence was caused by coagulase-negative *Staphylococcus*.

Hovelius and Josefsson (1979) demonstrated better results regarding control of infection with the use of antibiotic-loaded cement beads as a spacer at the time of resection arthroplasty. Duncan and Masri (1994) introduced the PROSTALAC (prosthesis of antibiotic-loaded acrylic cement) system and reported a failure rate of 7% due to infection in two-stage revision THA for infection. We used gentamicin-loaded cement spacers during the interval period in 17 of the 18 patients, and gentamicin-loaded cement beads in 1 patient. The exact role of antibiotic-loaded cement in eradicating infection remains unclear, however.

The duration and route of administration of antibiotics remain controversial. Most reports suggest 4–6 weeks of intravenous administration (Salvati et al. 1982, McDonald et al. 1989, Lieberman et al. 1994), while others have used intravenous antibiotics for only 5–7 days (Haddad et al. 2000)—or did not even use systemic antibiotics except for prophylaxis (Ammon and Stockley 2004) and relied on local depots of antibiotics in the form of beads. Higher levels of antibiotics can be delivered in the early days of the interval using a combination of systemic antibiotics and antibiotic-impregnated cement. During the later stages when concentrations of the eluted antibiotic drop (Masri et al. 1998), high levels can be maintained using systemic antibiotics.

While good results have been reported with the use of anatomic-specific proximal femoral allografts for femoral reconstructions (Blackley et al. 2001), the use of structural allografts for acetabular reconstructions is controversial. Whereas some authors have reported failure rates as high as 45–72% after 2–16 years (Hoikka et al. 1993, Hooten et al. 1994, Shinar and Harris 1997), other reported failure rates have been as low as 10% at 5–13 years (Paprosky and Magnus 1994, Böhm and Banzhaf 1999). We consider the amount of cover-

age of the acetabular component by the allograft to be the most important factor in achievement of mechanical stability of the acetabular construct.

We conclude that the use of bulk allograft bone in a two-stage reconstruction protocol in cases of infected THA gives satisfactory results. It should be considered in cases complicated by severe bone stock loss, where standard revision techniques are not an option.

No competing interests declared.

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