MEDIUM TERM RESULTS OF IMPACTION GRAFTING OF ACETABULAR DEFECTS WITH IRRADIATED ALLOGRAFT BONE

N GARNETI, AP DAVIES**, EJ SMITH***, ID LEARMONTH*****

SUMMARY

Allograft bone is commonly used to reconstruct areas of bone loss around failed total hip replacements. Irradiated allograft bone may help to reduce the risk of transmission of infectious agents from donor to recipient. The purpose of this study was to establish the results of impaction bone grafting of acetabular defects using frozen, irradiated allograft bone.

All patients treated by a single surgeon with impaction bone grafting of acetabular defects at revision total hip replacement were reviewed retrospectively. All operations were performed during the period 1994-2000. The mean follow-up was 50months (range 30-96months). Case notes and Xrays were reviewed and analysed. The Paprosky grade of acetabular defects was determined from the pre-operative Xrays and the surgeon's note at the time of operation. Post-operative Xrays were reviewed to establish the extent and rate of new bone ingrowth. Functional outcomes were determined by way of self-administered questionnaires.

46 patients were identified as fulfilling the inclusion criteria for the study. Six had died and seven had incomplete records. Complete records and Xrays were obtained for 33 patients who underwent revision hip arthroplasty with impaction bone grafting of the acetabulum using frozen, irradiated bone.

There were 21 patients with a previously uncemented acetabular component and 12 with a cemented component. The Paprosky classifications of the defects were as follows: 3 type 1, 10 type 2A, 4 type 2B, 4 type 2C, 10 type 3A and 2 type 3B. Titanium mesh and/or a reinforcement ring were used in all cases of uncontained acetabular defects.

There were no complications associated with the bone grafts and no patient required reoperation. Review of serial Xrays confirmed ingrowth of host bone. The functional results obtained were as follows: 17 patients (52%) could walk an unlimited distance. 11 patients (33%) required no walking aids whilst a further 17 (52%) required a single cane to mobilise. 21 patients (64%) were able to use public transport after the operation. 20 patients (61%) reported little or no pain. 9 patients (28%) had no limp and 14 patients (42%) had a slight limp. Overall 29 patients (88%) declared themselves to be satisfied with the outcome of their surgery. 32 patients (97%) improved functionally after their operation.

These results indicate that satisfactory results can be achieved with impaction bone grafting using frozen, irradiated allograft bone. The use of irradiated bone graft can potentially reduce the risks of disease transmission from donor to recipient without compromising the surgical results.

INTRODUCTION

Rates of revision arthroplasty of the hip have increased dramatically over the last two decades. The reconstruction of lost acetabular bone stock around failed arthroplasty prostheses is a major challenge in revision hip replacement surgery. Acetabular bone stock deficiencies can be re-constructed by bone impaction grafting with morcellized allograft bone chips. A cemented cup can then be used in the reconstructed acetabulum. A number of long-term follow-up studies have been published demonstrating favourable results for such acetabular reconstructions both primary and revision hip replacement[1,2,3,4]. Such studies are based on the use of bone chips made from femoral head autografts or fresh frozen femoral head allografts. A recent small series[5] suggested

* MRCS, Senior House Officer in Orthopaedics, Southmead Hospital, Bristol BS10 5NB.
** MRCS, Specialist Registrar in Orthopaedics, Southmead Hospital Bristol BS10 5NB.
*** FRCS, Consultant Orthopaedic Surgeon, Southmead Hospital Bristol BS10 5NB.
**** FRCS, Professor and Head and Department of Orthopaedic Surgery, University of Bristol, Bristol Royal Infirmary, Bristol BS2 8HW.

that acceptable results could be achieved using impacted freeze-dried allograft bone chips.

One important consideration when using allograft bone is the potential for cross infection between donor and recipient of transmissible agents such as Human Immunodeficiency Virus and Hepatitis viruses[6]. The transmissible agent of the spongiform encephalopathies has yet to be formally identified, but the potential for transmission of the so-called 'prion'particle is clearly of concern in the present climate. Careful screening of donors can reduce but not eliminate the risk of cross-infection. Some centres have chosen to irradiate allograft bone in order to reduce this risk further. Irradiated bone could be expected to have differing osteo-inductive and mechanical properties to fresh frozen or freeze dried allograft.

The purpose of this study was to establish the medium term results of impaction bone grafting of acetabular defects using frozen, irradiated allograft bone and to compare these results with those previously published. This retrospective analysis of 33 patients describes the clinical outcome of acetabular revision with frozen, irradiated allograft bone.

MATERIALS AND METHOD

This was a retrospective review of 33 patients operated on by a single surgeon (EJS) with impaction bone grafting of acetabular defects with frozen, irradiated allograft bone at the time of revision total hip replacement. All operations were performed during the decade 1994-2000.

Patients were excluded if there was any evidence of infection at revision surgery or if impaction bone graft was not required. Bone grafting of the femoral canal was not considered in the present study. The mean duration of follow-up was 50months (range 30-96 months). The case notes and Xrays of every patient were reviewed and analysed. If either notes or Xray records proved incomplete, the patient was excluded from the study. The Paprosky grade of acetabular defects was determined from the pre-operative Xrays and the surgeon's note at the time of operation. Post-operative Xrays were reviewed to establish that satisfactory bone incorporation occurred by determining radio-density, trabeculation and presence or absence of progressive radio-lucent lines. Patients underwent Xray investigation immediately post-operative, at 3 months, 6 months, 1 year and annually thereafter. Xrays included an AP pelvis low centred to include the whole of the femoral component and a lateral of the affected hip. Functional outcome for every patient was determined by way of a patient self-administered questionnaire which included questions on the level of pain, walking distance, limp and the use of a support, ability to climb stairs, use public transport, donning shoes and socks, and their overall improvement, satisfaction and a willingness to have a repeat operation if required.

Allograft bone was obtained from femoral heads donated at the time of primary total hip replacement, and were processed at the Oxford Bone Bank based at the John Radcliffe Hospital, Oxford which serves the South-West of the UK. All patients gave their informed consent in advance of bone donation and completed a standardised health-screening questionnaire. Donated bone was harvested under sterile conditions in a clear air environment under antibiotic cover and was immediately stored by deep-freezing at –80°C. Bacteriological cultures were taken at the time of harvesting, before the bone was placed in the bone bank. These were incubated in broth for 24 hours and then sub-cultured onto blood agar for a further 24hours. Femoral heads found to be contaminated were discarded without further sterilisation. In all cases, further culture swabs were taken when the bone was opened for use in impaction grafting.

Secondary sterilisation in the form of irradiation using gamma rays and accelerated electrons was carried out on all allograft bone used in this study. It has previously been demonstrated that 15kGy of irradiation achieved 95% sterilisation and that 30kGy caused tissue damage[7]. A dose of 25kGy was therefore chosen as a suitable compromise. Twelve or more hours of gamma irradiation is required to sterilise the allograft.

The femoral head allografts were stored intact at –80°C until they were required and were supplied individually to be used by the surgeon.

At surgery, the acetabular cup was exposed and removed with any cement. Care was taken to remove any membrane from behind the cup and the defect was classified according to the Paprosky classification. The acetabulum was cleared back to a bleeding trabecular bone bed. Uncontained defects were converted to contained defects using Titanium cages and mesh. When necessary, sclerotic areas were perforated with multiple fine drill holes, and the bone bed washed with pressurised lavage. The allograft femoral heads

were defrosted and morcellized with a Noviomagnus bone mill using the course blade to generate bone chips of <5mm maximum diameter. Once containment of the acetabular bone defect had been achieved, morcellized allograft bone was impacted until the defect had been reconstituted. The revision acetabular component was then sited and secured according to the surgeon's preference.

RESULTS

46 patients were identified as fulfilling the inclusion criteria for the study. Six had died and seven had incomplete clinical records. These patients were therefore excluded from further analysis. No complications relating to the procedure were found in any of these cases. Complete records and Xrays together with an outcome questionnaire were obtained for 33 patients (33 hips) who underwent revision hip arthroplasty with impaction bone grafting of the acetabulum with frozen, irradiated allograft bone. These patients form the data set for the study. There were 13 men and 20 women in the study group. Their mean age at the time of surgery was 69 years (range 36-95 years).

There were 21 patients with a previously uncemented acetabular component and 12 with a cemented component. The Paprosky classification of the defects were recorded as 3 type 1, 10 type 2A, 4 type 2B, 4 type 2C, 10 type 3A and 2 Type 3B. Titanium mesh and/or a re-enforcement ring were used in the reconstruction of all cases of un-contained acetabular defects.

There were no complications associated with the use of allogenic bone grafts and no patient required further revision surgery during the follow up period. There were no positive cultures from swabs taken at the time of allograft use. No case was complicated by infection. Review of serial Xrays to determine radio-density, trabeculation and presence or absence of progressive radio-lucent lines, confirmed progressive in-growth of host bone into the region of the allograft impaction in all cases. Progressive bone resorption was not seen in this study.

Functionally, 17 patients (52%) could walk an unlimited distance. 12 patients (36%) could mobilise over short distances outdoors, 1 patient (3%) was mobile indoors and the remaining 2 patients (6%) could transfer from bed to chair. 11 patients (33%) required no walking aid whilst a further 17 patients (52%) required a single cane for support. 21 patients (64%) were able to use the public transport. (Table 1).

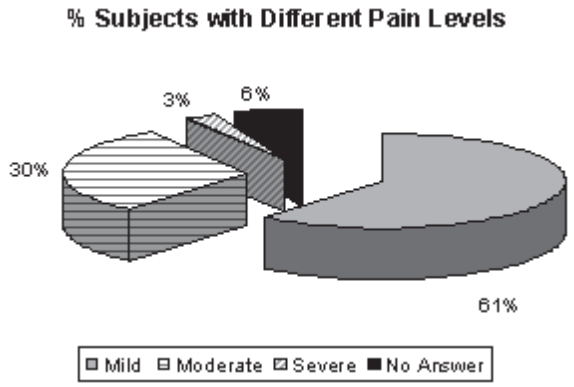
20 patients (61%) reported little or no pain**.** 10 patients (30%) reported moderate pain and one patient (3%) reported severe pain. 22 patients (67%)were free from pain at night whilst the remaining 11 patients (33%) did experience some night pain (Figure 1).

9 patients (28%) had no limp and 14 patients (42%) had a slight limp. (Figure 2). 12 patients (36%) were able to flex their hip to > 90° (Figure 3).

Overall, 29 patients (88%) declared themselves to be satisfied with the outcome of their operation.

Table 1
Functional Results of 33 Patients

Functional Task	Numbers of Patients			
Walking Distance	Unlimited 17 (52%)	Few Yards 12 (36%)	Indoors Only 1 (3%)	Bed to Chair 2 (6%)
Need for Support	None 11 (33%)	One Crutch 17 (52%)	Two Crutches 2 (6%)	Unable to walk 1 (3%)
Climbing Stairs	Normally 6 (18%)	With Handrail 24 (73%)	Unable 3 (9%)	
Donning Shoes and Socks	With Ease 9 (27%)	With Difficulty 18 (55%)	Unable 4 (12%)	No answer 2 (6%)
Sitting	Any Chair 11 (33%)	Raised chair only 22 (67%)	Unable to Sit 0 (0%)	
Using Public Transport	Able to Use 21 (64%)	Unable to Use 12 (36%)		



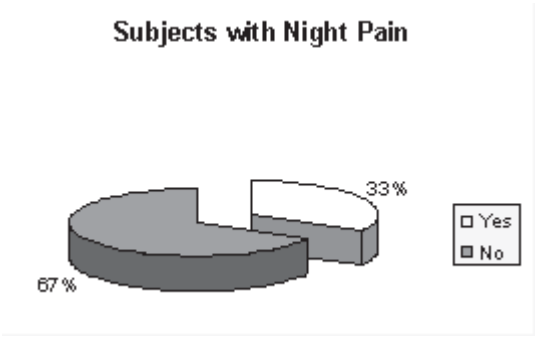


Figure 1a **Figure 1b**

Figure 1a and b: Patients experiencing pain at last follow up.

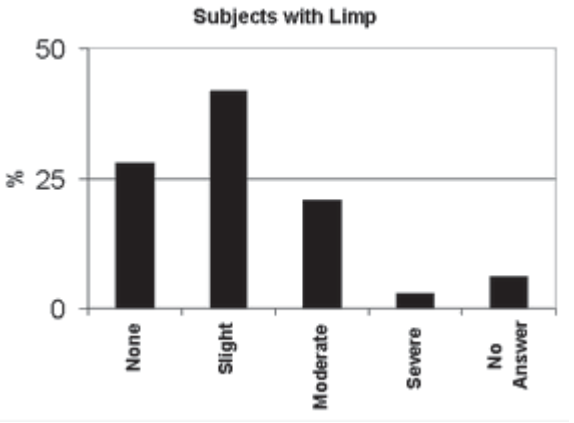


Figure 2: Patients experiencing limp at last follow up.

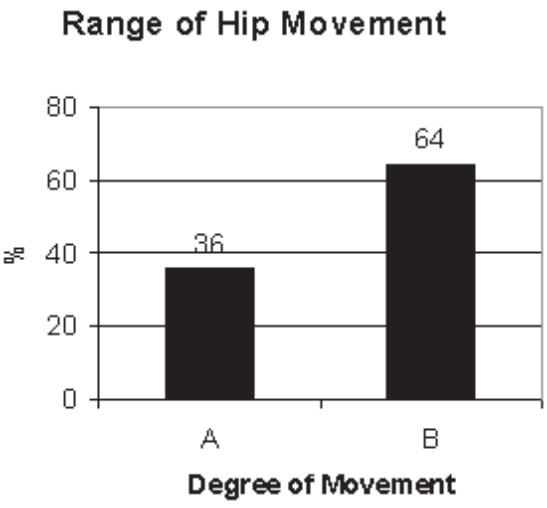


Figure 3: Patients range of hip movement at last follow up.

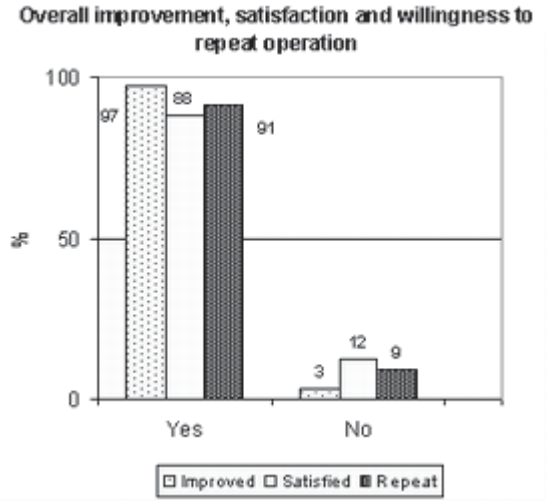


Figure 4: Patient's assessment of clinical improvement and overall satisfaction.

32 patients (97%) improved functionally after their operation and 30 patients (91%) stated that they would be prepared to have a revision arthroplasty for a second time, if required (Figure 4).

DISCUSSION

Restoration of both acetabular and femoral bone stock is one of the major challenges facing the revision arthroplasty surgeon. Both autograft and allograft have been used successfully to reconstitute such defects[1,2,3,4]. These operations are expensive, are a significant challenge to the surgeon and carry an increased risk of complications for the patient.

Autograft bone contains viable osteoblasts and is capable of osteoproduction. It also overcomes the problem of cross infection. Only very small volumes of autologous bone can realistically be harvested at revision surgery and these are usually

insufficient for the purposes of re-constructing significant defects around the hip. Allograft bone provides an osteoconductive scaffold over which host bone can grow. There may remain some growth factors within this scaffold that may prove to be osteo-inductive by exciting the host osteoblasts to produce more bone. The allograft will not however contain any live cells capable of osteoproduction.

Allograft bone is now widely used in revision hip arthroplasty and is an attractive solution to the problem of donor site morbidity and insufficient autograft availability. One major concern with allograft bone is the potential risk of transmission of infection from donor to recipient. There is a significant rate of infection associated with the use of massive allografts in revision hip arthroplasty[9]. Infection rates of 5% and 11.7% have been reported after allogenic bone grafting[9,10]. Four cases of HIV transmission from bone transplantation despite sterile harvesting techniques have been recorded in the USA[11]. Furthermore histological examination of femoral heads that would have been considered suitable for bone bank donation has detected a range of occult pathological conditions. These included avascular necrosis, osteomata and malignant tumours such as chondrosarcoma and lymphocytic lymphoma[12]. Secondary sterilisation with irradiation reduces the risk of transmission of infection or malignant cells. Irradiation also reduces allograft immunogenicity, but may adversely affect the strength of the bone. Freezing and thawing of the bone to –70°C has no effect on the mechanical properties of the cortical bone, however prolonged storage at sub-zero temperatures leaves no viable cells. Freeze-drying of the bone markedly diminishes its tortional and bending strength without affecting compressive and tensile strength[13].

Since the technique of impacting morcellized cancellous bone into acetabular defects was introduced[14], there have been numerous reports of successful outcomes[1,2,3,4], but these have been confined to use of femoral head autograft in primary arthroplasty or fresh frozen allograft in revision arthroplasty. Thien et al[5] reported the clinical outcomes of 7 patients who underwent acetabular reconstruction with processed freeze-dried allograft bone at an average follow-up of 7 years. One patient revised for septic loosening failed due to recurrent sepsis. The authors report that radiographic incorporation of the graft was seen in all remaining cases. There were no failures for aseptic loosening. All patients were reported to be mobile, although some used a support for mobilising outdoors. Four patients had no pain and two patients had mild symptoms.

The impaction bone grafting technique described by Slooff[14] has been adapted to address bone loss in the proximal femur[15]. Histological analysis has demonstrated host bone ingrowth using fresh frozen allograft with this technique[16]. Hamadouche[17] has reported the ten year outcome of a single patient who underwent a femoral structural allograft with frozen irradiated bone. At ten years, revascularisation of the graft had occurred to a depth of only 5mm. The non-revascularised bone had undergone substantial resorption and showed evidence of extensive micro-fracture formation. The authors are aware of one previous series that reports the use of irradiated allograft bone for reconstruction of bone stock in the context of revision total hip replacements. Oakeshott and colleagues[18] report the results of 72 patients followed up for between 6 and 72 months. Allograft took the form of cadaveric and live donations and had received 2.5Mrad of radiation. Bone reconstruction of the femur or acetabulum used structural or morcellized graft or both. 31 procedures were performed for protrusio and of these, 24 used morcellized femoral head allograft whilst the remainder used segmental allograft. In 12 cases, metallic rings were used to achieve containment of the defect. Additional mesh was required in 2 cases. 14 patients underwent cemented acetabular component fixation, whilst 17 were uncemented including 9 bipolar hemi-arthroplasty designs. The authors report 30 of the grafts consolidated. Superior and medial migration of the prosthesis was reported in 11 of the 31 cases including 8 of the 9 bipolar prostheses. All 11 cases had morcellized allograft rather than segmental bone suggesting a sub optimal outcome in 46% of cases treated in this way. Mean pre-op Harris hip scores for this group were 29 rising to 69 after surgery. The authors conclude that a fixed acetabular component is preferable to a mobile hemi-arthroplasty design in the context of acetabular allograft reconstruction.

The results of the current series are equivalent or superior to those reported previously. In the current series, 20 patients (61%) had no pain and 11 patients (33%) were able to walk without the need for walking aids. 29(88%) of the 33 patients were satisfied and 32 (97%) have functionally improved

after their surgery. 30 patients (91%) would be willing to have a revision hip surgery again, if required. These results indicate that satisfactory outcome can be achieved using frozen, irradiated allograft bone to reconstruct acetabular defects at revision hip arthroplasty. The use of frozen, irradiated bone graft can in addition reduce the potential risk of transmission of infection from donor to recipient without compromising the surgical results. No infections were encountered in our study which compares favourably to the results of previous authors[9,10] using non-irradiated allograft. The findings of our study support the use of frozen, irradiated allograft bone for the reconstruction of acetabular defects encountered at revision hip arthroplasty.

REFERENCES

1. Schreurs BW, Slooff TJJH, Buma P et al. Acetabular reconstruction with impacted morcellized cancellous bone graft and cement: a 10-15 year follow-up of 60 revision arthroplasties. J Bone Joint Surg (Br) 1998; 80 (3); 391-395.
2. Welten MLM, Schreurs BW, Buma P et al. Acetabular reconstruction with impacted morcellized cancellous bone autograft and cemented total hip arthroplasty. J Arthroplasty 2000; 15 (7): 819-824.
3. Rosenberg WW, Schreurs BW, de Waal Malefijt MC et al. Impacted morcellized bone grafting and cemented primary total hip arthroplasty for acetabular protrusion in patients with rheumatoid arthritis: An 8 to 18 year follow-up study of 36 hips. Acta Orthop Scand 2000; 71: 143-146.
4. Schreurs BW, van Tienen TG, Buma P et al. Favourable results of acetabular reconstruction with impacted morcellized bone grafts in patients younger than 50 years. Acta Orthop Scand 2001; 72 (2):120-126.
5. Thien TM, Welten MLM, Verdonschot N et al. Acetabular revision with impacted freeze-dried cancellous bone chips and a cemented cup: a report of 7 cases at 5 to 9 years follow-up. J Arthroplasty 2001; 16 (5): 666-670.
6. Tomford WW. Transmission of diseases through transplantation of musculoskeletal allografts. J Bone Joint Surg (Am) 1995; 77-A: 174-54.
7. Meeker IA, Gross RE. Low temperature sterilisation of organic tissue by high voltage cathode ray irradiation. Science 1951; 114: 284.
8. Paprosky WG, Bradford MS, Younger TI. [Classification of bone defects in failed prosthesis]. Chir Organi Mov 1994; 79(4): 285-91.
9. Tomford WW, Thongphasuk J, Mnkin HJ et al. Frozen musculoskeletal allografts: a study of the clinical incidence and causes of infection associated with their use. J Bone Joint Surg (Am) 1990; 72-A: 1137-43.
10. Lord CF, Gebhardt MC, Tomford WW et al. Infection in bone allograft. J Bone Joint Surg (Am) 1988; 70-A: 369-76.
11. Nemzek JA, Arnolxky SP, Swenson CL. Retro-viral transmission by the transplantation of connective tissue allografts. J Bone Joint Surg (Am) 1994; 76-A: 1036-41.
12. Palmer SH, Gibbons CLMH, Athanasou NA. The pathology of bone allograft. J Bone Joint Surg (Br) 1999; 81-B: 333-5.
13. Conrad EU, Ericksen DP, Tenler AF et al. The effect of freeze-drying and rehydration in cancellous bone. Clin Orthop 1993;290: 279-284.
14. Slooff TJ, Huiskes R, van Horn J et al. Bone grafting in total hip replacement for acetabular protrusion. Acta Orthop Scand 1984; 55 (6): 593-596.
15. Gie GA, Linder L, Ling RSM et al. Impacted cancellous allografts and cement for revision total hip arthroplasty. J Bone Joint Surg (Br) 1993;75:14-21.
16. Nelissen RG, Bauer TW, Weidenhielm LR et al. Revision hip arthroplasty with the use of cement and impaction grafting. Histological analysis of four cases. J Bone Joint Surg (Am) 1995;77:412-422.
17. Hamadouche M, Blanchat C, Meunier A et al. Histological findings in a proximal femoral structural allograft ten years following revision total hip arthroplasty. A case report. J Bone Joint Surg (Am) 2002;84:269-273.
18. Oakeshott RD, Morgan DAF, Zukor DJ et al. Revision total hip arthroplasty with osseous allograft reconstruction. Clin Orthop 1987; 225: 37-61.