Early results of whole femoral head allograft with articular cartilage for acetabular impaction grafting in revision hip replacements

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ABSTRACT

INTRODUCTION Extensive bone loss associated with revision hip surgery is a significant orthopaedic challenge. Acetabular reconstruction with the use of impaction bone grafting and a cemented polyethylene cup is a reliable and durable technique in revision situations with cavitary acetabular bone defects. Some use cancellous graft alone whilst others morselise the whole femoral head after removal of articular cartilage. This paper asks, if it really necessary to use pure cancellous graft?

PATIENTS AND METHODS Forty-two acetabular revisions using impacted morselised bone graft without removal of articular cartilage and a cemented cup were studied retrospectively. The mean follow-up was 3 years (range, 2–5.6 years). Clinical and radiographic assessment was made using the Oxford hip score, Hodgkinson's criteria (1988) for socket loosening and the Gie classification (1993) for evaluation of allograft consolidation and remodelling.

RESULTS Forty (95%) sockets were considered radiologically stable (type 0, 1, 2 demarcations) and two (5%) sockets were radiologically loose (Type 3 demarcation). There was no socket migration in our series. Twenty-seven (64%) cases showed good trabecular remodelling (grade 3). Twelve (29%) cases showed trabecular incorporation (grade 2). Only three (7%) cases showed poor allograft incorporation (grade 1). Average pre-operative Oxford hip score was 41 and postoperative hip score was 27. There have been no socket re-revisions (100% survival) at an average of 3 years.

CONCLUSIONS Early radiological and clinical survival results with retaining articular cartilage of femoral head allografts are similar and comparable to other major studies for acetabular impaction bone grafting in revisions. Minimal loss of allograft mass is 40% in obtaining pure cancellous graft. When there is a limited supply and demand of allograft, saving up to 40% of the material is a valuable and cost-effective use of scarce resources.

KEYWORDS

Femoral head – Allograft – Articular cartilage – Acetabular impaction – Hip replacement

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The number of patients requiring revision hip arthroplasty is constantly rising. This is a significant orthopaedic challenge due to the extensive bone loss associated with revision surgery which often requires bone grafting. Acetabular reconstruction using bone graft and a cemented polyethylene cup is a reliable and durable technique for revision situations with acetabular bone stock defects.¹

It is accepted that all acetabular components will fail in time.² If extensive areas of bone lysis are not addressed with bone graft during revision, subsequent revisions will be extremely difficult. It is important to attempt reconstruction of the skeleton biologically during revision surgery by using bone graft. Slooff and colleagues² published results of impaction grafting demonstrating a stable graft in 79% of cases at 15 years and Ornstein *et al.*³ produced 71% stable graft at 2-year follow-up.

Slooff *et al.*⁷ used pure cancellous graft alone whereas Brewster *et al.*¹² used the corticocancellous portion of the femoral head allograft after removing the articular cartilage. There have been no reports in the literature of using the whole femoral head while retaining the articular cartilage. The aim of this paper was to assess the initial mechanical stability and the capacity for biological incorporation and remodelling after impaction grafting using the whole femoral head including residual articular cartilage.

Patients and Methods

Forty-two sockets were revised between 2002–2004, using impacted morselised bone graft without removal of cartilage. Cemented polyethylene cups were implanted in all 42

Figure 1 (A) Pre-operative hip radiograph showing big cavitary bone defect in the acetabulum (aseptic loosening of the socket and stem). (B) Thirty-month follow-up showing excellent remodelling of the allograft.

hips. Thirty-six hips were revised due to aseptic loosening as a single-stage procedure. Six hips were revised for infection (Fig. 2A) and they underwent two-stage revision. Thirty-eight hips had cavitary (Fig. 1A) contained defect (AAOS type 2).⁴ Four hips had combined cavitary and segmental defects (AAOS type 3)⁴ and they were treated with structural bone graft in addition to impaction bone grafting. There were 23 (55%) women and 19 (45%) men with a mean age at revision of 66 years (range, 34–96 years). As a protocol, all patients were reviewed at 3 months, 1 year, 3 years and 5 years. Mean follow-up was 3 years (range, 2–5.6 years). Pre-operative Oxford hip score and postoperative hip score at 3 months, 1 year, 3 years and 5 years were recorded.

Surgical technique

All the operations were performed by a single surgeon. A lateral incision with trochanteric osteotomy was used. Osteoarthritic femoral heads harvested at the time of primary total hip replacement were the source of fresh-frozen femoral heads. Only the soft tissue was removed while no effort was made to remove cartilage from the femoral heads. The frozen femoral heads were morselised using the

Tracer bone mill, with a medium-sized cutter and a hand crank. The milled bone graft was washed with saline and then compressed in a sterilised potato-grater for delipidation. The morselised allograft bone was impacted into the acetabular defect covering the entire surface if necessary. Cementation of the socket was performed using vacuum mixed CMW 2 cement with gentamycin, and a flanged Opera cup was implanted in all 42 cases. The antibiotic prophylaxis used (intravenous teicoplanin and oral ciprofloxacin as per the unit protocol) was given to all patients until results of bacteriology were available; for thrombosis prophylaxis, low molecular weight heparin was given.

Radiographic assessment for demarcation

All radiographs from the pre-operative examinations to the most recent follow-up were assessed. Acetabular loosening was assessed using the criteria of Hodgkinson *et al.*⁵ With this system, a cup was considered to be loose when there was more than 1 mm of radiolucency at the cement bone interface involving all three zones (Fig. 2B) or migration of the socket. Evaluation of allograft consolidation and incor-

Figure 2 (A) Pre-operative radiograph of case 2 (septic loosening of the socket and stem). (B) Two-year follow-up radiograph showing radiolucent line in all three zones between cement–bone interface.

poration was made using the classification of Gie *et al.*,⁶ which is described under three headings:

1. *No change*: completely unchanged graft findings as compared with the first postoperative radiographs.
2. *Trabecular incorporation*: any change in the structure of the graft as compared with the first postoperative radiographs but not fulfilling the very strict criteria of grade 3.
3. *Trabecular remodelling*: the graft has changed into a pattern in harmony with the adjacent acetabular bone (Fig. 1B).

Results

Forty-two hips were followed for a mean of 3 years (range, 2–5.6 years). The mean pre-operative Oxford hip score was 41 (range, 30–58 points) and the mean postoperative Oxford hip score was 27 (range, 13–50 points).

Forty (95%) sockets were considered stable (Type 0, 1, 2 demarcation). Only two (5%) sockets showed complete demarcation at the cement bone interface (Type 3 demarcation) and thus were considered radiologically loose. There was no socket migration in our series. Evaluation of allograft consolidation revealed 27 hips (64%) with good trabecular remodelling and they were classified grade 3 allograft. Twelve hips (29%) showed trabecular incorporation without remodelling and they were classified grade 2 allograft. Only three hips (7%) showed no change in the graft quality at the time of most recent follow-up and they were classified grade 1 allograft.

Out of 40 stable sockets, 27 (67.5%) hips showed good trabecular (grade 3) remodelling of the allograft. Only 13 hips (32.5%) out of 40 stable sockets showed poor trabecular remodelling of the allograft. However, all radiologically loose sockets showed poor trabecular remodelling.

Survivorship analysis

With revision of the cup for any reason as the end-point, the survival rate was 100% at 3 years (95% CI, 2.3–5.3 years). Twenty-seven cups with grade 3 allograft were 100% radiologically stable at 4.4 years (95% CI, 3.9–4.9 years). Of acetabular cups with grade 2 allograft, 92% were radiologically stable at 2.9 years (95% CI, 2.1–3.6 years).

Discussion

The technique of impaction bone grafting in the acetabulum was first introduced by Slooff and co-workers in Nijmegen, in the late 1970s.⁷ The technique was introduced into the UK by Ling at Exeter in 1987. Slooff and colleagues² published their results of impaction grafting with 79% stable graft at 15 years and Ornstein *et al.*⁵ produced 71% stable graft with 2-year follow-up. The aim of impaction grafting is to

restore living bone around the implant without affecting its stability. Immediately after impaction bone grafting, the mechanical properties of the impacted bone are used to provide the initial implant stability. Later, we believe that bone grafts can be remodelled and gradually transformed into normal living bone (biological property).⁸

The osteoarthritic head harvested during primary total hip replacement is the commonest source of fresh frozen femoral heads for impaction bone grafting. It contains three types of tissue: cancellous bone in its bulk, cortical bone (mainly from the neck) and remnants of articular cartilage.⁹ Slooff *et al.*⁷ reported the use of cancellous graft alone. Brewster *et al.*¹² and Gie *et al.*⁶ used most of the femoral head including cortical portion but without articular cartilage. No team has yet reported using the whole femoral head including the articular cartilage.⁹ In our study, we have not removed the articular cartilage from the femoral head allograft but we have removed the synovial lining and other soft tissue attachments. Our technique has advantages such as reduced operating time and reduced bone loss due to femoral head allograft preparation. It has been shown that the minimum loss of graft material is 40% of initial graft mass when obtaining pure cancellous graft from a femoral head allograft, 25% of graft mass is lost in obtaining corticocancellous graft after removing cartilage, and less than 10% loss of initial graft mass when using the whole femoral head without removing the articular cartilage.⁹

The early function of the impaction graft is to provide mechanical stability to the prosthesis. Some groups argue that implant stability is affected by the graft size,^{10,11} the ideal size is larger, and research suggests that 8–10-mm diameter chips provide the best initial stability. Brewster *et al.*¹² claim that the absolute particle size is less important than the grading. The initial mechanical stability of a prosthetic component implanted into a contained defect that has been augmented with morselised bone graft will be greatest when the graft has a well-graded particle size profile and has been effectively compacted. The mechanical strength of well-graded morselised bone was greater than that of a more uniform size. The mechanical performance of morselised bone derived from frozen whole femoral heads and impacted into a contained cavity is improved by the provision of a profile of particle size. Shear strength is improved by adding measured quantities of small and very small fragments.¹² A study comparing bone in-growth into non-compacted and compacted bone showed that increasing compaction reduces bony in-growth.¹⁵ The presence of cartilage will minimally increase the compaction.⁹

A comparison of bony in-growths into compacted material with a non-ideal grade particle-size distribution with that ideal grade particle mix showed increased in-growth into the non-ideal grade graft.¹⁴ We believe that we are able to achieve comparable results with other published studies

because milling the osteoarthritic head, which contains patchy areas of cartilage, produces different sizes of particles. This non-uniform graft mass improves resistance against shear stresses. It is our assumption that we are able to get non-uniform graft by retaining the cartilage of osteoarthritic femoral head allograft. Further research will be needed to corroborate this. Furthermore, we feel that, by retaining the articular cartilage, the compactness of the graft is reduced slightly but it promotes bone in-growth into the graft material. The dynamics of the relationship between initial stability and ultimate re-incorporation of the graft into the host bone are poorly understood.¹² Allograft is degraded in the biological process of bone remodelling and this may affect the implant stability. It is also unclear how important incorporation of the graft is, provided that the construct remains stable over a long period and does not itself increase the formation of particulate debris to stimulate macrophage activity and further skeletal resorption.¹²

In our study, only two sockets showed full demarcation at the end of most recent follow-up (2 years and 9 months) but they were clinically asymptomatic with good bone stock and remain under close review. Interestingly, all the radiologically loose sockets (2 sockets, 5%) showed poor allograft trabecular remodelling (100%). Our results suggest that allograft remodelling is an important determinant of long-term success of impaction grafting and implant stability.

We have used osteoarthritic femoral head allograft harvested during the primary hip replacement. It is difficult to quantify the amount of cartilage left with femoral head allograft. Further follow-up is needed to assess the long-term outcome.

Conclusions

The radiological and clinical survival results with femoral head allografts retaining their cartilage are similar and comparable to other major studies for acetabular impaction bone grafting in revision hip arthroplasties. In the future, increasing numbers of patients will require revision utilising bone allograft. At least 40% of the allograft mass is lost in obtaining pure cancellous graft and 25% loss of initial graft mass in obtaining corticocancellous graft without cartilage. When there is a limited supply and high demand for allograft,¹⁵ using the extra 25–40% of the available allograft without reducing the long-term success of the procedure is undoubtedly worthwhile.

References

- Schreurs BW, Busch VJ, Welten ML, Verdonschot N, Slooff TJ, Gardeniers JW. Acetabular reconstruction with impaction bone-grafting and a cemented cup in patients younger than fifty years old. *J Bone Joint Surg Am* 2004; **86**: 2385–92.
- Schreurs BW, Bolder SB, Gardeniers JW, Verdonschot N, Slooff TJ, Veth RP. Acetabular revision with impacted morsellised cancellous bone grafting and a cemented cup. A 15- to 20-year follow-up. *J Bone Joint Surgery Br* 2004; **86**: 492–7.
- Ornstein E, Franzen H, Johnsson R, Stefansson A, Sundberg M, Tägil M. Five year follow up of socket movements and loosening after revision with impacted morsellised allograft bone and cement. *J Arthroplasty* 2006; **21**: 975–84.
- D'Antonio JA, Capello WN, Borden LS, Bargar WL, Bierbaum BF, Boettcher WG *et al*. Classification and management of acetabular abnormalities in total hip arthroplasty. *Clin Orthop* 1989; **243**: 126–37.
- Hodgkinson JP, Shelley P, Wroblewski BM. The correlation between the roentgenographic appearance and operative findings at the bone–cement junction of the socket in Charnley low friction arthroplasties. *Clin Orthop* 1988; **228**: 105–9.
- Gie GA, Linder L, Ling RS, Simon JP, Slooff TJJ, Timperly AJ. Impacted cancellous allografts and cement for revision total hip arthroplasty. *J Bone Joint Surg Br* 1993; **75**: 14–21.
- Slooff TJ, Huiskes R, Van Horn J, Lemmens AJ. Bone grafting in total hip replacement for acetabular protrusion. *Acta Orthop Scand* 1984; **55**: 593–6.
- Toms AD, Barker RL, Jones RS, Kuiper JH. Impaction bone grafting in revision joint replacement surgery. *J Bone Joint Surg Am* 2004; **86**: 2050–60.
- Bavadekar A, Cornu O, Godts B, Delloye C, Van Tomme J, Banse X. Stiffness and compactness of morsellized grafts during impaction. An *in vitro* study with human femoral heads *Acta Orthop Scand* 2001; **72**: 470–6.
- Giesen EB, Lamerigts NM, Verdonschot N, Buma P, Schreurs BW, Huiskes R. Mechanical characteristics of impacted morsellised bone grafts used in revision total hip arthroplasty. *J Bone Joint Surg Br* 1999; **81**: 1052–7.
- Verdonschot N, Schreurs B, van Unen J, Slooff T, Huiskes R. Cup stability after acetabulum reconstruction with morsellized grafts is less surgical dependent when larger grafts are used. *Trans Orthop Res Soc* 1999; **24**: 867.
- Brewster NT, Gillespie WJ, Howie CR, Madabhushi SPG, Usmani AS, Fairbairn DR. Mechanical considerations in impaction bone grafting. *J Bone Joint Surg Br* 1999; **81**: 118–24.
- Tagil M, Aspenberg P. Impaction of cancellous bone grafts impairs osteoconduction in titanium chambers. *Clin Orthop* 1998; **352**: 231–8.
- Pratt JN, Griffon DJ, Dunlop DG, Smith N, Howie CR. Impaction grafting with morsellised allograft and tricalcium phosphate-hydroxyapatite: incorporation within ovine metaphyseal bone defects. *Biomaterials* 2002; **23**: 3309–17.
- Galea G, Kopman D, Graham BJ. Supply and demand of bone allograft for revision hip surgery in Scotland. *J Bone Joint Surg Br* 1998; **80**: 595–9.