Nine-year results of whole femoral head allograft with articular cartilage for acetabular impaction grafting in revision hip replacement

E Drampalos, A Fadulelmola, R Mohammed, D Shaw, S Subramanian, KD Jain, J Hodgkinson

Wrightington, Wigan and Leigh NHS Foundation Trust, UK

ABSTRACT

INTRODUCTION Acetabular impaction bone grafting with a cemented polyethylene socket aims to reconstitute the bone stock in hip revision. This is an effective but resource intensive and time consuming technique. Usually, the articular cartilage is removed from the femoral head allograft. Our objective was to assess the late results of using the whole femoral head, retaining the cartilage.

METHODS Forty-two acetabular revisions using impacted morselised bone graft (retaining the articular cartilage) and a cemented socket were studied retrospectively. The mean follow-up duration was 9.3 years (range: 6–13 years). Clinical and radiological assessment was made using the Oxford hip score, the classification of Hodgkinson *et al* (1988) for socket loosening and the classification of Gie *et al* (1993) for evaluation of allograft incorporation.

RESULTS Twenty-seven sockets (75.0%) were radiologically stable, six (16.7%) were radiologically loose and three (8.3%) had migrated. Thirty cases (83.3%) showed good trabecular remodelling and six (16.74%) showed trabecular incorporation without remodelling. Six patients were lost to follow-up. Kaplan–Meier analysis calculated a survival rate of 94.5% at a mean of 9.3 years (95% confidence interval: 8.1–10.4 years) for all reasons of failure, with two re-revisions.

CONCLUSIONS The nine-year results of the aforementioned technique are comparable with other major studies. Particularly when the supply of allograft and operative time are limited, retaining the articular cartilage of the femoral head is a safe and successful alternative.

KEYWORDS

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

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CORRESPONDENCE TO

Efstathios Drampalos, E: edrampalos@yahoo.gr

In 2013 more than 75,000 primary total hip replacements were performed in the UK and over 8,500 revisions.¹ Given the ageing population, these numbers are set to rise.

As it is accepted that all implants will fail in time, some loss of host bone is inevitable.² This is the result of a combination of stress shielding, osteolysis and potential infection and can be increased during removal of the failed implants. Acetabular reconstruction using bone graft and a cemented polyethylene socket is an effective technique for cavitory defects with the aim of reconstituting bone stock.² Impaction bone grafting in total hip replacement was reported initially by Hastings and Parker in 1975.³ In 1984 Slooff *et al* modified the technique and described it for the first time as impaction bone grafting.⁴ Published results include 75% survivorship for the cup at 20 years.²

Slooff *et al* described the use of cancellous bone chips⁴ and Gie *et al* used morselised whole femoral heads without the articular cartilage.⁵ The only report in the literature of using the whole femoral head with the articular cartilage is from our department, with favourable early results in 42

patients.⁶ This paper now reports the assessment at 6–13 years for 36 of these 42 patients, who underwent revision hip replacement with the impaction grafting technique using the whole femoral head and retaining the cartilage.

Methods

Between 2002 and 2004, 42 cemented polyethylene cups were revised using impacted morselised bone graft without removal of the cartilage. During the same period, there was a shortage of femoral heads in our institution. This meant we had to either limit the number of revisions or use less allograft material for every revision. Furthermore, as gamma irradiation and freezing adversely affect the osteoinductive or osteoconductive potential and strength of the graft, fresh frozen osteoarthritic femoral heads were used without removing the cartilage.⁷ In 36 cases, a single stage revision was carried out (aseptic loosening) while 6 hip revisions were performed as two-stage procedures (infection). Thirty-eight hips had a cavitory contained defect (American

Academy of Orthopaedic Surgeons [AAOS] type 2).⁸ In the remaining four cases, there was a combination of segmental bone loss and cavitory deficiency (AAOS type 3), and an additional structural allograft was used.

A retrospective review of radiography and electronic medical records was conducted. Demographic data, diagnosis, acetabular loosening, allograft incorporation, clinical outcome and complications were recorded. The criteria of Hodgkinson *et al* were used to assess loosening of the cemented cup, considering radiolucencies at the cement–bone interface (Table 1).⁹ A cup was deemed to be loose when there was more than 1mm of radiolucency at the cement–bone interface in all three zones (Fig 1). For the evaluation of allograft incorporation, the empirical classification of Gie *et al*⁵ was used:

- > *No change*: Completely unchanged graft findings as compared with the first postoperative radiographs
- > *Trabecular incorporation*: Any change in the structure of the graft as compared with the first postoperative radiographs but not fulfilling the criteria of trabecular remodelling below
- > *Trabecular remodelling*: The graft has changed into a pattern in harmony with the adjacent acetabular bone (Fig 2).

Table 1 Hodgkinson's classification of roentgenographic demarcation of the socket⁹

Type 0	No demarcation at the cement–bone interface
Type 1	Demarcation (1mm) of outer third only
Type 2	Demarcation (1mm) of outer third and middle third
Type 3	Complete demarcation (1mm)
Type 4	Socket migration (change of socket position as judged on serial x-rays)

Figure 1 Radiography at seven years showing radiolucent line in all three zones between cement–bone interface

Figure 2 Radiography at five years showing trabecular remodelling of the graft

Surgical technique

A trochanteric osteotomy was used in all cases and all operations were performed by the senior author. Fresh frozen osteoarthritic femoral heads obtained during primary total hip replacements were the source of bone allograft, removing only the soft tissue while retaining the cartilage (Fig 3). The allograft was morselised using the Tracer bone mill (Tracer Designs, Santa Paula, CA, US), with a medium sized cutter and a hand crank. The fragmented bone graft was washed with saline and compressed in a sterilised potato grater for delipidation. The allograft was then impacted into the acetabular defect, and cementation of the socket was performed using vacuum mixed CMW™ 2 cement with gentamicin (DePuy, Warsaw, IN, US) and a flanged Opera socket (Smith & Nephew, London, UK).

All patients were given antibiotic prophylaxis (intravenous teicoplanin and oral ciprofloxacin as per unit protocol) until the results from bacteriology excluded infection. Low molecular weight heparin was used for prophylaxis against thrombosis.

Statistical analysis

The Kaplan–Meier method was used to estimate implant survivorship, using removal or revision of the implant for any reason as the endpoint. Analysis was performed using SPSS® version 19 (IBM, NY, US).

Results

During the study period, 42 cemented polyethylene cups were revised using impacted morselised bone graft without removal of the cartilage. The patient group comprised 19

Figure 3 Fresh frozen osteoarthritic femoral head obtained during primary total hip replacement after removing the soft tissue but with the cartilage retained

men (45%) and 23 women (55%). The mean age at the index operation was 66 years (range: 34–96 years). Six patients were lost to follow-up but thirty-six (86%) were followed for a mean of 9.3 years (range: 6–13 years).

Twenty-seven sockets (75.0%) were radiologically stable (Hodgkinson types 0–2), six (16.7%) were radiologically loose, with complete demarcation at the cement–bone interface (Hodgkinson type 3), and three (8.3%) had migrated (Hodgkinson type 4). With regard to allograft incorporation, 30 cases (83.3%) showed good trabecular remodelling and 6 (16.7%) showed trabecular incorporation without remodelling.

One patient had persisting dislocation. There were also five cases of trochanteric non-union and four cases of heterotopic ossification around the revised hip replacement. Furthermore, there were two re-revisions treated with a cemented total hip replacement with impaction bone grafting and a structural bone graft.

Survivorship analysis

The Kaplan–Meier survivorship was 94.5% at a mean of 9.3 years (95% confidence interval: 8.1–10.4 years), with revision of the cup for any reason as the endpoint.

Discussion

In revision hip arthroplasty, compacted morselised bone grafting aims to biologically reconstitute deficient bone stock of the acetabular or femoral side, rendering any subsequent surgery easier. The outcomes of this technique were reviewed at 20 years by Schreurs *et al* with 75% survivorship for the cup.² Obviously, the long-term results depend on the biological process of incorporation of the graft. The interaction between graft and host bone consists of three different mechanisms:¹⁰

- > *Osteoinduction*: Morselisation increases the surface area and the release of growth factors.
- > *Osteoconduction*: The impacted graft functions as a scaffold for the ingrowing bone.
- > *Mechanical loading*: Bone formation is stimulated by deformation as a result of loading.

The hypothesis of allograft incorporation is supported by histological studies.^{11,12} However, according to other studies, fibrous ingrowth may also provide mechanical stability, indicating that allograft incorporation and remodelling is not a prerequisite for a good clinical result.^{15,14} In fact, in a histological study of 14 stable cemented stems (retrieved during postmortem examination or biopsy) it was concluded that fibrous tissue and unincorporated graft particles could provide a composite tissue capable of carrying load.¹⁵ Furthermore, thin fibrous membranes were not detected on radiography and so one should be cautious in interpreting radiographic changes with regard to tissue viability. Consequently, there is still discussion about the type of and necessity for graft incorporation. It may be that if there is no complete integration of the allograft, then fibrous ingrowth can provide acceptable stability.

The most common source for impaction bone grafting material is fresh frozen femoral heads from osteoarthritic hips harvested during primary hip replacement, containing cortical bone of the neck, cancellous bone and remnants of articular cartilage.¹⁶ In the original technique of impaction bone grafting, Slooff *et al* used cancellous bone.⁴ The idea is that the structure of cancellous bone should allow more effective remodelling and incorporation.⁴ The above hypothesis was questioned by Kligman *et al*, who instead proposed the use of cortical allografts with improved mechanical performance.¹⁷ Gie *et al* and Brewster *et al* used whole femoral heads as allograft material, including the cortical bone but removing the articular cartilage.^{5,18}

Both large bone chips and smaller grafts produced with a bone mill are used. Nevertheless, a comparison of bone ingrowth into compacted material of a particle size distribution that is not ideal with ingrowth into material of an ideal mix of particle sizes (ideal distribution ensures that voids between larger particles are not filled with smaller particles) showed increased ingrowth into the graft in the former.^{18–20}

The procedure of impaction grafting is, however, technically demanding, requiring trained surgeons and special equipment. It can also be time consuming, particularly when producing big bone chips by hand.²⁰ Furthermore, it is expensive and resource intensive. Dedicated bone banks that pay rigorous attention to graft preparation are required and three or more femoral head allografts are often used for every revision.^{21,22} The technique of impaction grafting used in our unit results in reduced operative time and a need for less femoral head allograft material. In fact, compared with the 10% of loss of the initial whole femoral head allograft mass when retaining the articular cartilage, a minimum loss of 40% has been shown when obtaining pure cancellous graft and 25% of graft mass is lost when obtaining cortico-cancellous graft but removing the cartilage.¹⁶ This is an

important parameter to consider in the modern era of economic crisis.

In a previous paper, our team presented the early results of using whole femoral osteoarthritic heads (with the articular cartilage) and the Tracer bone mill for morselisation.⁶ The outcome in 42 sockets at 2–5-years was encouraging, including a survival rate of 100% with revision of the cup for any reason as the endpoint. Moreover, 95% of the sockets were considered radiologically well fixed (Hodgkinson types 0–2) and 64% of cases showed good trabecular remodelling.

At follow-up review at a mean of 9.5 years, 27 sockets (75.0%) were radiologically stable (Hodgkinson types 0–2) and in fact, 30 cases (85.3%) showed good trabecular remodelling. Of the six sockets (16.7%) found to be radiologically loose (Hodgkinson type 3), five were clinically asymptomatic with good bone stock and remain under review. Survivorship was 94.5%, using removal or revision of the implant as the endpoint. Furthermore, the two re-revisions comprised a patient with pain who had socket migration, classified as radiologically loose (Hodgkinson type 4), and another with recurrent dislocation of the hip and with Hodgkinson type 3 demarcations (radiologically loose). Neither of the sockets in these two cases were found to be infected after completion of the clinical, laboratory and imaging evaluation.

The nine-year results of our technique are comparable with other published studies. In our department, asymptomatic patients with good bone stock and radiologically loose sockets (Hodgkinson type 3) or with socket migration (Hodgkinson type 4) remain under close review but do not necessarily require revision surgery. The 30 cases (85.3%) with good trabecular remodelling are indicative of a high rate of incorporation. Interestingly, 27 sockets (75.0%) were considered radiologically stable (Hodgkinson types 0–2), contributing to the medium-term success of our technique.

It is difficult to quantify the amount of cartilage left at the allograft but this is likely to be small as the harvesting is performed from osteoarthritic femoral heads during primary hip replacement. The small amount of cartilage does not contribute to the incorporation of the impacted graft and so it is unlikely to be the determining factor of the final result. In addition, it is our assumption that milling the osteoarthritic head, which contains patchy areas of cartilage, produces different sizes of particles, favouring bony ingrowth.

Conclusions

Our medium-term results with femoral head allografts retaining the cartilage are comparable with those in other major studies for acetabular impaction bone grafting in revision hip arthroplasty. According to the trends in hip replacement, the number of patients requiring revision or even re-revision surgery is likely to increase and impaction bone grafting is a more 'biological' technique to preserve bone

stock. It is, however, expensive and resource intensive. This is an important parameter to consider in the modern era of economic crisis. Particularly when the supply of fresh frozen femoral head allograft material and operative time are limited, retaining the articular cartilage of the femoral head is a safe and effective alternative.

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