Clinical and radiographic assessment of cementless acetabular revision with morsellised allografts

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Abstract The aim of this study was to evaluate the clinical and radiographic results of cementless acetabular revision with deep frozen morsellised allografts. Sixty-one patients (65 hips) underwent acetabular revision using cementless components and deep frozen morsellised allografts. Fifty-seven hips (53 patients) were reviewed at a mean of 105.1 months (range 72–180 months) after revision. The study group included 29 males and 24 females with a mean age of 46.4 years. One cup underwent further revision for aseptic loosening and two were defined as radiographic failures. The mean time for allograft incorporation was 12.5 months (range 6–24 months) after index surgery. The mean Harris hip score of the patients improved from 61.1 points preoperatively to 91.6 points postoperatively. Linear and cavitary osteolysis was observed in two and 12 hips, respectively. The acetabular revision using cementless components with deep frozen morsellized allografts provides favourable clinical and radiographic results, although the initial disease and age may adversely affect the outcomes.

Résumé L'objectif de cette étude est d'évaluer les résultats cliniques et radiographiques de la chirurgie de révision acétabulaire associant allogreffes morcelées, cryoconservées.

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Matériel et méthode : 61 patients (65 hanches) ont bénéficié d'une reprise avec cupule sans ciment et allogreffes morcelées cryoconservées. 57 hanches (53 patients) ont été revues en moyenne à 105,1 mois (de 72 à 180 mois) après la révision. Ce groupe comprend 29 hommes et 24 femmes avec un âge moyen de 46,4 ans. **Résultats :** une cupule a nécessité une nouvelle reprise pour un descellement aseptique et 2 ont été cataloguées comme échec sur le plan radiographique. Le temps moyen de l'incorporation de l'allogreffe a été de 12,5 mois (entre 6 et 24 mois), le score moyen de Harris de ces patients s'est amélioré de 61,1 points en préopératoire à 91,6 points en postopératoire. Des ostéolyses linéaires et cavitaires ont été observées respectivement sur 2 et 12 hanches. **Conclusions :** la technique de révision acétabulaire utilisant un composant non cimenté avec des greffes morcellées cryoconservées permet d'obtenir des résultats cliniques et radiographiques fiables néanmoins, la pathologie initiale et l'âge des patients peuvent avoir des effets négatifs sur l'évolution.

Introduction

After total hip arthroplasty (THA), the loosening process of acetabular components often results in a cavitary defect, and in more serious cases, a combined defect will also develop. The best approach for the reconstruction of acetabular defects remains controversial. Cemented cups may not be optimal for acetabular revision because bone defects make mechanical setting difficult and the eburnated surface makes anchoring the bone cement difficult [1–3]. Although the cementless cup can prevent abnormal tissue reaction to cement in acetabular revision [4], the Norwegian Arthroplasty Register reported that failure rates were highest in acetabular revisions performed with cementless

cups [5]. Bone transplantation contributes to the success of acetabular revision arthroplasty by restoring acetabular bone defects and stabilising prosthetic fixation [4]; however, the reported rate of mechanical failure of acetabular cups is high, with failure rates between 32% and 66% at 5.9 to 16 years [6–8].

This study reports the clinical and radiographic results of a mid- to long-term study of acetabular revision using deep frozen morsellised allografts and cementless cups.

Materials and methods

Patients

Between April 1995 and December 1999, 61 patients (65 hips) underwent acetabular revision arthroplasty with deep frozen morsellised allografts and cementless hemispherical acetabular cups. Of the original 61 patients (65 hips), eight patients' data were excluded because of loss of follow-up ($n=5$) and death ($n=3$). The remaining 53 patients (57 hips; 29 men, 24 women) were reviewed at a mean follow-up time of 105.1 months (range 72–180 months). The mean age of patients at the index revision surgery was 46.4 years (range 24–75 years). The diagnosis at the time of the primary arthroplasty was avascular osteonecrosis of femoral head in 24 hips (42.1%), secondary osteoarthritis in 17 hips (29.8%), primary osteoarthritis in six hips (10.5%), ankylosing spondylitis (AS) in seven hips (12.3%), and fracture of the femoral neck in three hips (5.3%). In primary arthroplasty, a cemented acetabular component was inserted in 37 hips (64.9%) and a cementless acetabular component in 20 hips (35.1%). The mean interval between the primary arthroplasty and revision was 120.8 months (range 22–268 months). The causes for revision were aseptic loosening in 51 hips, septic loosening in three hips, and polyethylene liner displacement with severe periacetabular osteolysis in three hips. On the basis of preoperative and immediate postoperative pelvic radiographs and the surgical notes, acetabular bone defects were classified according to the American Academy of Orthopaedic Surgeons' (AAOS) system [9]. The deficiency was categorised as type II (cavitary defect) in 42 hips (73.7%) and type III (combined defect) in 15 hips (26.3%) in this series.

Allograft preparation

A whole femoral head, obtained under sterile conditions from a live donor with osteoarthritis undergoing primary total hip arthroplasty (THA), was used for the allografts. Immediately after harvesting, the donated femoral head was then quarantined in a profound hypothermia refrigerator at -80°C for six months. At the time of allograft surgery, the

femoral head was thawed to room temperature in 2% Povidone-Iodine (Shanghai Welltone Material Technology Co. Ltd., China) and then washed with saline solution (0.9%). The cartilage and soft tissue were denuded, and then the bone was chipped into 5–10 mm pieces with rongeur. These bone chips were washed in 75% alcohol for ten minutes, and then three times in 500 ml saline solution (0.9%) to remove fat and marrow.

Surgical technique

A meticulous debridement of the acetabulum was performed to remove all fibrous membrane, interposed soft tissue, and cement from the cemented primary acetabulae. In 42 acetabulae categorised as cavitary defect (AAOS type II), the defects were located in superior and lateral, superior and medial, or direct medial, with anterior and posterior columns of the acetabulum. In 15 acetabulae categorised as combined defect (AAOS type III), the defects involved less than one-third of the circumference of the acetabular rim and were localised in the superolateral or anterior columns. The acetabulum was under-reamed by 2 mm prior to acetabular cup insertion. After the defects were addressed by tightly impacting the morsellised allograft, additional impaction was obtained by reverse reaming, and then a cementless porous hemispherical cup sized approximately 2 mm larger than the last reamer was implanted into the acetabulum. Among 15 acetabulae with combined defect (AAOS type III), three cups were placed in high hip centre in order to be in contact with living host bone. A jumbo cup was implanted in 36 hips and the mean diameter of these cups was 66.7 mm (range 64–70 mm) [10].

The cup was at least 50% in contact with the host bone to ensure the potential bone ingrowth and mechanical support. Adjuvant screws were inserted into the posterosuperior quadrant to secure the initial stability of the cup. Three screws were inserted in 23 of the hips, four screws in 23 hips, five screws in five hips, six screws in one hip, and one screw in one hip. The acetabular cups used were the Harris-Galante in four hips, Harris-Galante II in 37 hips, and Trilogy (Zimmer; Warsaw, Indiana, USA) in 16 hips. All of the femoral head implants were changed in this series. The diameter of femoral head implant was 28 mm in 53 hips (93.0%) and 22 mm in four hips (7%). In 34 hips (59.6%), the loosening femoral stem was also revised at the time of cup revision.

Postoperative regimen

Postoperative management included systemic antibiotics for five days and Indomethacin for seven days as a prophylaxis against heterotopic ossification. Passive movement was allowed 24 hours after the operation, and the patients used

crutches for two months, followed by the use of a cane until they were comfortable without support. Most patients were permitted full weight bearing without walking aids by three months. Five patients required the use of a cane up to six months due to the complicated reconstruction of the acetabulum and femur.

Follow-up

Patients were followed both clinically and radiographically at three months, six months, and one year and at annual intervals postoperatively. Clinical evaluation was performed using the Harris hip rating system (HHS).

Radiographic follow-up

Anteroposterior (AP) and lateral radiographs of the hip were taken at each follow-up. The diameter of the femoral head was used as the reference to correct for magnification of the measurements. The polyethylene liner wear was assessed by Livermore's method [11]. The coverage of the cup was measured on the AP radiograph of the hip as described by Wilson et al. [12].

The incorporation of the allograft was assessed according to Conn's method [13]. The osseous union of the allograft was defined as the presence of clearly delineated trabeculae bridging the host-graft junction. The graft was judged to be incorporated when its cancellous structure had acquired the same radiodensity as that of the supporting pelvic bed, with a continuous trabecular pattern throughout.

Linear and cavitary osteolysis was determined according to the zonal system of DeLee and Charnley. The area of these lesions was quantified by measuring the maximum diameter and the widest area perpendicular to this diameter, as seen on the AP radiograph.

The following radiographical signs were defined as acetabular loosening: (1) migration of the cup > 4 mm in either the horizontal or the vertical direction, (2) radiolucent line of > 2 mm in all zones, (3) breakage of the adjuvant screws, and (4) rotation of the cup $> 5^\circ$.

Survivorship analysis

Kaplan-Meier survivorship analysis was used to estimate the probability of retention of the acetabular cups from the time of the index revision to one of the following end points: repeat revision for any reason or definite radiographic loosening of the acetabular cup.

Statistical analysis

Statistical analysis was conducted with SPSS for Windows version 13.0 (SPSS Inc., Chicago, Illinois, USA). The

significance of the findings was evaluated with a paired *t*-test for comparison of all paired variables. A *P* value of less than 0.05 was considered statistically significant.

Results

Three hips were defined as clinical or radiographic failures in this cohort study. The first case displayed the absorption of transplanted allograft and reappearance of severe acetabular defects in zones 1 and 2. When the patient underwent femoral component revision for periprosthetic femoral fracture, the acetabular cup rerevision was performed at 24 months after the index cup revision. In the second case the cup inclination changed from 44° to 64° , three adjuvant screws broke, the cup migrated 16.7 mm superior-medially, and the transplanted allograft disappeared. The third case developed radiolucent lines around the cup and a gap up to 2 mm; however, the transplanted allograft had a radiodensity equal to that of the host bone and displayed a continuous trabecular pattern throughout.

At final review, the mean HHS improved from preoperative 61.1 points (range 29–79 points) to postoperative 91.6 points

Fig. 1 Radiograph made before revision of the hip of a 57-year-old woman who underwent acetabular revision demonstrating loosening of the acetabular component with creation of combined defect (AAOS Type-III)

(range 70–100 points; $p < 0.05$) in the 56 hips (in 52 patients, except for the case received re-revision). Thirty-seven hips (66.1%) had HHS scores greater than 90 points and 13 hips (23.2%) had HHS scores between 80 and 89 points. Therefore, 50 hips (89.3%) were rated as excellent or good clinical results, four hips (7.1%) were rated as fair, and two hips (3.6%) were classified as poor clinical results.

The average inclination of the implanted cups was 42.3° from horizontal (range $27\text{--}54^\circ$). The average postoperative bony coverage of the cup was 98% (range 80–100%). The annual polyethylene liner wear rate was a mean of 0.13 mm (range 0.00–0.91 mm).

Radiological evidence of allograft incorporation was observed in most patients at a mean of 12.5 months (range 6–24 months) after the index revision. Clearly delineated trabeculae had bridged the host-graft junction and allografts had acquired the same radiodensity as that of the host bone, with a continuous trabecular pattern throughout (Figs. 1, 2, 3).

Periacetabular osteolysis was found in 14 hips (24.6%) at the final follow-up—two hips were defined as linear osteolysis and 12 hips as cavitory osteolysis. Of the two hips with linear osteolysis, one was present in zones 1 and 2 and the other in zones 1, 2, and 3 where the radiolucent gap was greater than 2 mm. Of the 12 hips with cavitory

Fig. 2 Radiograph of the hip of a 57-year-old woman who underwent acetabular revision made six months after acetabular cup revision with deep frozen morsellised allograft and a hemispherical cementless acetabular cup

Fig. 3 Radiograph of the hip of a 57-year-old woman who underwent acetabular revision, made 144 months postoperatively, showing the incorporation and remodelling of transplanted morsellised allograft, with no signs of radiolucency, and the cup was well fixed

osteolysis, seven involved zones 1 and 2 (a mean of $29.4\text{ mm} \times 16.3\text{ mm}$), two were in zone 2 ($29.6\text{ mm} \times 21.8\text{ mm}$), two in zone 1 ($26.0\text{ mm} \times 18.1\text{ mm}$), and one in zone 3 ($38.4\text{ mm} \times 14.0\text{ mm}$). Among 12 hips with cavitory osteolysis, four were defined as new osteolysis and eight as reappearance of the initial osteolysis with the absorption of the transplanted allografts.

Survivorship analysis

Using repeat revision as the end point, Kaplan-Meier survivorship analysis of the cups yielded a cumulative survival rate of 98.2% (95% confidence interval, 94.9–100%) at 24 months. Kaplan-Meier survivorship of the cups, using repeat revision or radiographic failure as the end point, was 92.1% (95% confidence interval, 83.1–100%) at 98 months.

Complications

Several complications were encountered over the course of the study. One patient required closed reduction after

dislocating a hip during a fall two months after index revision. Another patient underwent PE liner exchange due to acute liner displacement at 101 months after the revision. Heterotopic ossification developed in four hips (7.0%) with the following distribution: one hip was rated as grade I, two as grade II, and one as grade III. One male patient developed sciatic nerve palsy and continued to display mild sensory loss at four years after surgery.

Discussion

In this study, we reviewed the results of acetabular reconstruction using deep frozen morsellised allografts and cementless cups.

The principle of acetabular reconstruction using cementless cups is at least 50% contact between the host bone and the cup for securing potential ingrowth [14, 15]. A bone graft with a diameter of 5–10 mm is considered appropriate for filling a defect with the impacting technique [16, 17]. The use of morsellised allografts is advantageous for several reasons: (1) the graft closely conforms to irregularities of the host bed, (2) the extended surface area of the morsellised bone graft can improve osseous inducibility by releasing more bone growth factors, and (3) morsellised bone grafts may stimulate bone remodelling due to their compliance and elasticity.

The incorporation of allografts is a vital factor for the success of acetabular cup revision [18]. The incorporation of allografts is a complicated process that is dependent upon osseous biological activity, the size of the graft, and the initial stability of the cup [19]. To reduce the risk of immunological rejection, the allografts used in this study were specially processed to remove antigens, and most patients displayed a successful incorporation of the allografts. Removing fat from the allograft with saline has been shown to significantly improve the strength of compacted allografts and increase the initial stability of cups [20]. In an acetabular model, the force required to tilt a cup by 16° increased from 3,450 N to 7,000 N when the graft was treated with saline to remove fat [21]. If the initial stability of an acetabular cup is protected for at least four months after revision surgery, then the allograft should successfully incorporate and bone strength should gradually improve. Consistent with previous findings, we observed radiographic incorporation of allografts into the host bone within 12 months of index revision in the majority of our patients [22]. Histological retrieval analyses have confirmed that remodelling gradually occurs, but with variable ingrowth [23]. However, bone scintigraph analysis has shown that the uptake becomes normal two to three years after surgery, demonstrating that slower remodelling continues for a considerably longer period.

The primary cause of cup radiographic failures in our study was the failure of the allograft incorporation. In one

case, the allografts transplanted in the loading region of the acetabulum were absorbed and the cups migrated in a superior-medial direction. The young age was one of the factors that correlated with the cup failure. In our study, the ages of three patients who were defined as failure were younger than 40 years old. The younger patients show a relatively higher demand for physical activity and thus put a great deal of stress on the prosthesis, which produces wear particles, which cause the osteolysis and implant loosening [24].

The most common complication in this study was periacetabular osteolysis. The cavitary defects reappeared in eight hips with absorption of the transplanted allografts and such osteolysis was considered a return to the previous osteolysis. New osteolysis developed in four cases at least eight years after revision. The absorption of the transplanted allografts and appearance of osteolysis may correlate with the immunological rejection due to remaining antigens in the allograft, incomplete debridement of the osteolytic tissue, and the new wear particles caused by poor grade polyethylene liner. The average wear of the polyethylene liner was 0.13 mm per year in our study. Such wear particles have been shown to induce periprosthetic osteolysis in previous studies [25].

A limitation of this study was the restricted ability of standard radiographs to assess the size of acetabular defect. Computerised tomography scans which were not used in our study should be used in future studies to better delineate the size and location of acetabular defects.

The findings of our study have encouraged us to reconstruct the cavitary acetabular defects and some combined acetabular defects using deep frozen morsellised allografts in conjunction with cementless cups. Further research is needed to determine which allograft processing technique will best promote biological incorporation and the stability of acetabular cups.

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