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Alumina Heads Minimize Wear and Femoral Osteolysis Progression After Isolated Simple Acetabular Revision

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Abstract

Background Patients with THA requiring cup revision for acetabular osteolysis may have a stable stem component without loosening. However, it is unclear whether isolated cup revision halts femoral osteolysis progression.

Question/purposes We asked (1) whether and to what degree osteolysis progresses after isolated acetabular revision with a change of the femoral head and (2) whether an alumina or metal bearing better reduces osteolysis progression and wear with a polyethylene (PE) cup.

Methods We retrospectively evaluated 150 patients who underwent 165 acetabular revisions but no treatment for

proximal femoral osteolysis in hips with stable femoral components. Mean age at revision was 63 years (range, 48–74 years). All hips received a new PE cup; 83 hips received new alumina heads and 82 new metal heads. Radiographs (mean followup, 15 years; range, 10–25 years) were assessed to measure osteolysis, loosening, and PE wear. Revisions of the femoral stem were recorded. **Results** An isolated cup revision with a change of the femoral head halted femoral osteolysis progression for 10 years in 133 hips (81%), with a greater percentage without progression in hips with alumina heads (99% versus 62% with metal head). Alumina heads were better than metal heads at reducing the area of osteolysis progression (47 versus 250 mm²) and wear (0.07 versus 0.14 mm/year) and increasing the survival probability before femoral revision (98% versus 85% at 15 years' followup).

Conclusions An isolated cup revision with a new alumina femoral head (in hips that have a stable stem component without loosening) usually halts femoral osteolysis progression (no change or osseous restoration) over 10 years if the osteolysis is less than 1000 mm².

Level of Evidence Level III, therapeutic study. See Instructions for Authors for a complete description of levels of evidence.

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Introduction

Osteolytic lesions around femoral component worsen over time [10], although the rate is highly variable. Patients with a THA that requires cup revision for loosening or osteolysis may have a stable stem component without loosening. Surgeons are thus faced with the question of whether these stable devices should be replaced routinely when the

acetabular implant is exchanged, particularly in the presence of femoral osteolysis. If the stem is not replaced but osteolysis is present, the surgeon will face the question of whether to treat these lesions with curettage and bone graft. Furthermore, when the stem has a Morse taper, it is possible to change the femoral head. Whether and to what degree these lesions progress after isolated acetabular revision with a change of the femoral head (new bearing surface) are unclear, although it is likely the causes of the acetabular loosening or osteolysis would contribute to the femoral osteolysis and may diminish after acetabular revision. If the femoral head is changed for an alumina or metal head, it is also unknown whether these two bearing surfaces minimize osteolysis progression to the same degree with a polyethylene (PE) cup.

We therefore determined (1) whether and to what degree the lesions of osteolysis progress during the 10 years after isolated acetabular cup revision with a change of the femoral head and which new bearing couple (alumina or metal head with a PE cup) is more likely to reduce (2) osteolysis progression and (3) PE wear.

Patients and Methods

We identified all 150 patients (165 hips) who had first hip revision between 1985 and 2000 and underwent change of only the acetabular component and no treatment of proximal femoral osteolysis in hips with stable femoral components. The femoral heads were changed on the Morse taper at the time of revision with alumina or metal heads. We selected for this study only hips that had the same manufacturer's stem, the same Morse taper, a femoral size of 32 mm, and an acetabular cup of PE or of alumina provided by the same manufacturer (CeraVer Osteal, Roissy, France). These arthroplasties were performed between 1978 and 1992, and during the same period, 4284 primary arthroplasties of the same design were implanted. During that same time, we also performed 184 isolated

acetabular revisions for implants of other designs and 325 hip revisions for cup and stem changes. There were 78 men and 72 women. Fifteen revisions were bilateral. The mean age at revision was 63 years (range, 48–74 years). Of the 165 hips, 83 had a new alumina head and 82 a new metal head implanted on the original taper (Table 1). Alumina heads were used in patients aged up to 65 years. The minimum followup was 10 years in both groups (alumina: mean, 15 years; range, 10–20 years; metal: mean, 17 years; range, 10–25 years). In the metal cohort, eight patients were lost to followup and nine died. In the alumina cohort, six patients were lost to followup and five died.

The indications for the use of the two femoral head designs (alumina or metal) evolved during the study period. Early in the study period (from 1985 to 1990), the alumina head was not used during revision according to the manufacturer's recommendation insisting on the need to exchange a used trunion and therefore to change the stem to avoid insufficient fixation of the head on a damaged taper (with a risk of fracture of the head or abnormal wear between the head and taper). After 1990, due to a better knowledge of alumina fixation on the Morse taper, ie, an alumina head was indicated according to patient age and osteolytic lesion size, we began to implant new alumina heads on the old Morse taper first in patients with an alumina head removed during the revision and then later in some patients who first had a metal head.

During revision to remove a ceramic head, the head was not directly stroked to avoid a head fracture or damage to the taper. A hammer stroke was performed on the shoulder of the stem in the same direction as the stroke that had previously fixed the femoral head. With the reaction force, the femoral head moved proximally on the taper and was gently removed with the hand without taper damage. After removing the original ceramic femoral head, the taper was inspected to determine whether the cone was normal or damaged. When a ceramic head (alumina or zirconia) is fixed on a metal taper, the taper causes an imprint in the bore of the head. This imprint is normally a homogenous ring.

Table 1. Demographic characteristics

Characteristic	Primary THA		Revision THA	
	Alumina-PE	Metal-PE	Alumina-PE	Metal-PE
Number of hips	72	93	83	82
Age (years)*	42 ± 8.3	57 ± 10.4	59.7 ± 7.2	67.4 ± 9.1
Acetabular graft (number of hips)			51	48
Acetabular reinforcement (number of hips)			40	35
Followup (years)†			15 (10–20)	17 (10–25)
Lost to followup (number of patients)			6	8
Dead (number of patients)			5	9

* Values are expressed as mean ± SD; † values are expressed as mean, with range in parentheses; PE = polyethylene.

We inspected this imprint after removing the femoral head from the taper (bore angle of $5^{\circ} 43'$). When the imprint was a perfectly symmetric ring and the taper had no visible damage, a new alumina head was implanted. When the imprint was asymmetric, the taper may have been damaged, and a new alumina head was not used on such a taper. When the Morse taper had first received a metal head, the imprint in the femoral head could not be analyzed, and the Morse taper was carefully analyzed. As a result, 19 patients had an alumina head for both the primary and revision arthroplasties; 21 had a zirconia head for the primary and an alumina for the revision; 43 had a metal head for the primary and an alumina head for the revision; 22 had an alumina head for the primary and a metal head for the revision; 10 had a zirconia head for the primary and an alumina for the revision; and 50 had a metal head for the primary and a metal head for the revision (Table 1).

On the femoral side, all patients had received the same femoral implant with an alumina head at the time of the primary arthroplasty. The stem was made of anodized titanium alloy (TiAl6V4) and was smooth and always cemented. The primary and revision arthroplasties were performed using a posterolateral approach. The tolerance limits within which the manufacturers operated for the new femoral heads were characterized by the sphericity and the surface roughness. The sphericity is the difference between the largest and the smallest diameters. The surface roughness (Ra) is the arithmetic mean of the absolute value of the deviation of the profile height as measured from the graphical center line using a contact profilometer. The alumina heads were 32 mm in diameter, had a spherical deviation of less than 15 μm , and had an Ra of 0.02 μm . The metal femoral heads were made of Z₄ CNMD 21-9-4 (ISO 5832-9) [11]. Their Ra was 0.07 μm before implantation and the spherical deviation was less than 50 μm . The acetabular component was a PE cup. Both components were fixed with cement (Palacos® G; Heraeus Medical GmbH; Hanau, Germany) containing antibiotics (gentamicin). We classified the acetabular bone loss on preoperative radiographs according to the classification system of Paprosky et al. [15]: 98 hips were Type I, 67 hips were Type II; and no hip was Type III. Contained acetabular bone defects were packed with morselized allograft, whereas relevant segmental bone defects were reconstructed with bulk allografts supported in 75 hips with the Kerboul acetabular reinforcement device (Stryker Howmedica, Herouville Saint Clair, France).

We evaluated the patients clinically and radiographically at 6 weeks, 3 months, 6 months, and then yearly. Patients were asked to rate pain on a 10-point VAS, and Harris hip score was calculated for patients who were able to return for followup. Three dislocations occurred at a mean time of 3 days (range, 1–8 days), with recurrent dislocation (four

times) in only one hip, but only one revision was necessary for recurrent dislocation (Table 2). Twelve patients (13 hips) were not able to return for followup and were contacted by telephone; they were asked to send radiographs and whether they had pain, dislocation, or revision.

At each radiographic evaluation, every patient had an AP radiograph of the pelvis and hip and a lateral view (Lequesne view) of the hip with the patient weightbearing. Subsequent revision of the cup or of the stem was defined as the end point of the analysis. To decrease the subjective evaluation of femoral bone loss during the evolution, the identifying information of dates were masked on the initial postoperative and most recent followup radiographs of each hip; these two radiographs were then compared, evaluating them for a difference in the proximal femoral bone stock by the method of Paprosky et al. [15] and by a direct measurement of the surface osteolysis on the calcar. The dates of the radiographs were revealed only after measurements. Two of us who were not treating surgeons (ND, YH) classified bone loss. The Paprosky femoral bone loss classification has an interobserver κ value of 0.42 and an intraobserver κ value of 0.54 [6]. On the femoral side, bone defects were limited to the calcar in 90% of the hips. All preoperative and immediate postoperative radiographs (AP and lateral view of hips) were available and were compared to those at last followup for measurement of osteolysis. Femoral osteolysis was defined as a new or expanding sharply demarcated lucency adjacent to the stem and beginning on the calcar. Each lesion was identified and traced on each radiograph with use of a semiautomated edge detection module (Photoshop®; Adobe Systems, Inc, San Jose, CA, USA), as described previously [9, 10]. The diameters and areas of the lytic lesions were then calculated from each tracing. To calculate the area of the osteolysis, we identified lesions and traced them on each axial cut using the Photoshop® semiautomated edge detection module. Intraclass correlation coefficients (ICCs) for interobserver and intraobserver reliabilities were calculated to quantify osteolytic changes seen on plain film radiographs by Smith et al. [20]. The ICCs for interobserver reliability on the simulated and actual osteolytic

Table 2. Comparison of rerevisions rates after revision with an alumina head (n = 83) or a metal head (n = 82)

Cause of revision	Number of hips	
	Alumina heads	Metal heads
Loosening of femoral stem		8 (9.6%)
Fracture and loosening of the femur		2 (1.4%)
Cup loosening		2 (2.4%)
Recurrent dislocation	1 (1.2%)	

lesions ranged from 0.90 to 0.96; the values for intraobserver (test-retest) reliability ranged from 0.97 to 0.98. We calculated the intraobserver and interobserver errors in our series: they were less than 16 mm². The accuracy of our method was also evaluated previously [10] and was 6 ± 4 mm². Preoperatively, the average osteolytic lesion size was larger ($p = 0.01$) for patients receiving alumina heads at revision (mean, 564 mm²; range, 18–981 mm²) than for patients receiving metal heads (mean, 321 mm²; range, 45–687 mm²). We also classified the radiographic changes in the proximal femoral bone stock as described by Bohm and Bischel [2]: A = increasing defects; B = constant defects; and C = osseous restoration. There are no published studies on the reliability of this classification system. To decrease the subjective evaluation of femoral bone loss during the evolution, changes on radiographs were classified C when restoration was noted with the two classifications (Paprosky classification and direct measurement of the surface osteolysis); changes were noted A when increasing defects were noted with the two classifications; and all other situations changes were noted B. The technique used for measurement of PE wear was adapted from a three-dimensional technique described previously [9, 10] used for both the measurement and accuracy. We measured femoral head penetration within the cup by comparison of initial postoperative and long-term followup films. All measurements were made from standard frontal and lateral views. Absence of loosening of the socket was defined as no cup migration exceeding 5 mm, no angular rotation exceeding 5°, and no continuous radiolucent line wider than 2 mm [5].

Descriptive analysis was performed to report mean and SDs for the continuous variables (age, area of osteolysis). Frequency distribution (%) was reported for the categorical variables (sex, presence or absence of acetabular bone graft, alumina versus metal head, failure versus nonfailure). We compared these continuous and categorical variables with dependent variables (femoral or acetabular revision, radiographic femoral or acetabular loosening, periprosthetic femoral fracture, PE wear) using nonparametric tests. Logistic regression was used for comparison of wear between alumina and metal heads; this analysis was adjusted for weight, age, sex, and cup thickness. We used Pearson's correlation to assess the relationship between wear rate and osteolytic lesion progression in the surface. We used Kaplan-Meier survivorship analysis to estimate the probability of retention of femoral acetabular components from the time of the index revision to aseptic revision. We compared the rate of survival between alumina and metal heads using the log-rank test (Prophet Version 5.0; BBN Technologies; Cambridge, MA, USA).

Results

An isolated cup revision with a change of the femoral head (Fig. 1) was able to halt femoral osteolysis progression (no change or osseous restoration) (Table 3) in 133 hips (81%) during a minimum period of 10 years (average, 15 years; range, 10–25 years). All 133 femoral implants of these hips were well fixed at most recent followup. During the same period, osteolysis progression was observed in 32 hips

Fig. 1A–D (A) A prerevision radiograph shows the hip of a patient with wear of the PE cup and femoral osteolysis; the femoral head was zirconia. (B) Osteolysis of the calcar at 1 year after isolated

acetabular revision (arrow) is shown; the femoral head is alumina. (C) Osteolysis of the calcar is shown 10 years later. (D) The osteolysis of the calcar (arrow) regressed 15 years later.

(19%). At most recent followup, the 32 hips with osteolysis progression were more likely to undergo rerevisions on femoral side (10 of 32; 31%) compared with the 133 hips without osteolysis progression (no rerevision on the femoral side). The causes of rerevision on the femoral side were eight loosening and two periprosthetic fractures associated with osteolysis progression in all these hips. Young age at revision and large osteolysis on the femoral side were associated ($p = 0.02$ and $p = 0.01$, respectively) with the risk of rerevision for the cohort at 10 years' followup. The remaining factors (sex, acetabular bone graft, acetabular reinforcement) were not associated with rerevision risk.

Alumina heads were better at halting femoral osteolysis progression (no change or osseous restoration; for example, see Fig. 2) (Table 3), with a greater percentage ($p = 0.02$) of hips without progression in the alumina head cohort (99%) than in the metal head cohort (62%). No femoral head fracture was observed in the alumina group. On the femoral side, despite the alumina heads being used in cases with worse osteolysis and in younger patients (Table 1), the average increase in area of osteolysis was smaller ($p = 0.02$) with alumina-PE friction couples (47 mm^2 ; range, -65 to 97 mm^2) than with metal-PE friction couples (250 mm^2 ; range, 135 – 658 mm^2), with a greater

percentage of femurs with increasing defects (Type A) observed in hips with metal heads (Table 3). Patients in the alumina head cohort had a higher percentage ($p = 0.01$) of patients with osseous restoration (Type C) than with increasing defects (Type A) compared with the metal cohort (Table 3). With the end point as revision for loosening or fracture of the femur (associated with increase osteolysis), the survival probability was greater with alumina heads than with metal heads: 100% and 89%, respectively, at 10 years' followup ($p = 0.02$); and 98% and 85%, respectively, at 15 years' followup ($p = 0.01$).

The mean rate of femoral head penetration was less with alumina heads than with metal heads. The mean linear PE wear was 0.14 mm/year (range, 0.09 – 0.21 mm/year) for hips with a new metal head and 0.07 mm/year (range, 0.05 – 0.12 mm/year) for hips with a new alumina head. After adjusting for weight, age, sex, and cup thickness, the mean rate of linear penetration was less ($p = 0.02$) for the alumina heads than for the metal heads. There was a correlation between the progression in area of osteolysis and the rate of wear ($R = 0.2$; $p = 0.03$).

Discussion

Isolated acetabular revision represents about 10% of revision hip arthroplasty [3] and only few reports [4, 12, 13] have been published. In some instances, retention of the stem may be beneficial as it may result in reduced morbidity, complications, blood loss, operative time, and cost. Recently, there have been reports [4, 12] of good results after retention of stable femoral components at the time of acetabular revision, supporting the notion that isolated revision of one of the components does not affect the survival of the other. However, none of these reports has

Table 3. Radiographic changes in the proximal femur in alumina heads ($n = 83$) and metal heads ($n = 82$)

Changes to the proximal femur	Number of hips	
	Alumina heads	Metal heads
A (increasing defect)	1 (1.2%)	31 (37.8%)
B (no change)	45 (54.2%)	49 (59.6%)
C (osseous restoration)	37 (44.6%)	2 (2.4%)

Fig. 2A–C (A) A prerevision radiograph shows the hip of a patient with cup loosening (zirconia head); the osteolytic lesion size was calculated to be 981 mm^2 and is the maximum lesion size treated with femoral head change in this series. (B) Osteolysis of the calcar at 1 year after isolated acetabular revision is shown; the femoral head is alumina. (C) The osteolysis of the calcar regressed 18 years later.

compared the influence of the bearing surfaces on wear after acetabular revision and there is little information regarding the results of isolated acetabular revision in cases in which a stable femoral implant is left in place and the femoral head changed on the Morse taper. The usual belief is that it is not necessary to change the femoral head and that revision of the acetabular component does not alter the survival of the stem. However, because the cup is subject to wear, and wear related to the bearing surfaces, this observation is not necessarily correct. Ceramics were introduced in the 1970s as an alternative bearing surface with superior wear characteristics compared with those of the established metal-on-PE couplings used at that time for THA. Nearly 40 years have passed, and metal-on-PE couplings continue to be the most commonly used bearing surfaces, particularly for hip revision. The failure of ceramic to supplant metal as the preferred femoral head material is principally due to the fact that fracture of the ceramic head has been reported in ceramic-on-PE couplings, not only in primary arthroplasties [1], but also in revision by Pulliam and Trousdale [17] who reported a case of breakage of a ceramic head implanted on a used taper. We therefore determined (1) whether and to what degree the osteolytic lesions progress during the 10 years after isolated acetabular cup revision with a change of the femoral head and whether an alumina or metal head with a PE cup better reduces (2) the risk of osteolysis progression and (3) PE wear.

We note several limitations to our study. First, we measured osteolysis only with radiographs. It is well known radiographs underestimate osteolysis compared with that observed on CT scans [10]; however, according to long-term followup and the accuracy of the measurements, our evaluation of osteolysis progression appears acceptable with radiographs. Second, we had no established protocol for the type of surgery performed and various strategies were adopted in this series with regard to revision surgery and implantation of a ceramic head on a stable femoral stem. Therefore, the alumina and metal heads were not selected at random, but since the alumina heads were used in cases with worse osteolysis, this bias is limited. Third, only patients undergoing acetabular revision surgery who had a primary arthroplasty with the same implant during the study period were included, which may have affected the ability to detect differences associated with other implants; however, there are only a few large series of isolated acetabular revisions in the literature, including Chen et al. [4], Lawless et al. [12], and Manning et al. [14] with 55, 42, and 26 hips, respectively, which have not evaluated the osteolysis progression on the femur. Our series seems to be the largest with isolated acetabular revision, and one of the advantages of our series is that surgery was performed with a consistent surgical technique and the same arthroplasty for both primary and revision,

which reduced some variability. Fourth, osteolysis was limited to 1000 mm² in our series of patients and we cannot comment on the progression with larger volumes of osteolysis.

To our knowledge, no study has evaluated whether an isolated cup revision is able to halt femoral osteolysis progression or the specific risk of loosening of the femoral stem at long-term followup. Our data show an isolated cup revision with a change of the femoral head (in hips that have a stable stem component) is able to halt femoral osteolysis progression (no change or osseous restoration) in 81% of the hips during a 10-year period. However, this isolated cup revision was not able to stop femoral osteolysis progression in 32 of the 165 hips and the number of rerevisions for femoral loosening was 10 of 32 in our series. The rerevision risk after isolated cup revisions and the factors that increase these risks of rerevision are not well known due to the low number of series in the literature and the short followup of most of the series [4, 12, 14]. The rerevision risk may be explained by the associated complications of the primary joint that preceded the revision procedure, prolonged operative time during the revision procedure, or complications during the revision procedure. Most of the series have reported rerevisions after isolated acetabular changes were in relation to postoperative instability or iterative acetabular loosening due to an increased loss of bone stock resulting from older patient age. However, these complications were infrequent in our series, and postoperative instability or iterative acetabular loosening was not a frequent cause of rerevision. This finding conforms to the results of another series [12]. However, probably because our followup is longer, we observed a problem that has not been reported yet in other series, namely, osteolysis progression and loosening of the femoral stem in some patients.

We found patients who underwent a simple acetabular revision procedure with metal-PE bearing surfaces were more likely to undergo osteolysis progression compared with patients who underwent the procedure with alumina-PE bearing surfaces. The lower incidence of osteolysis observed in this series on radiographs with alumina-PE bearing surfaces is consistent with the results of other studies performed in primary arthroplasties [19]. A decrease of osteolysis with an alumina-PE coupling (compared with metal-PE) was reported in primary arthroplasties by Saito et al. [18]. Sugano et al. [21] reported similar results with longer followup of the same group of patients. Corrosion products or electric phenomena could also be a reason to observe more osteolysis in the metal head cohort since the metals of the head and trunion were not the same.

The average linear wear rates in revision arthroplasties of 0.14 mm/year for metal heads and 0.07 mm/year for alumina heads in our study are consistent with previously

reported ceramic-on-PE and metal-on-PE wear rates in primary arthroplasties [9, 10, 18, 22]. They have demonstrated a relatively wide range of wear rates, but most report lower wear rates with alumina heads. The decrease of osteolysis in association with low wear rates with implantation of a new alumina femoral head confirms the correlation between wear rates and osteolysis in revision surgery in other reports [8, 17, 21]. Furthermore, a restoration of the proximal femur with decreasing osteolysis was observed in some patients with a new alumina-PE bearing surface, suggesting osteolysis may be reversible if the progression of debris is minimized. The decision to retain a femoral head on a Morse taper or to change to a new one at the time of acetabular revision has, to date, been a matter of judgment, with little information in the literature to direct the thought process. In the last decade, however, there has been renewed interest in ceramic bearing surfaces in THA. It is now believed many of the fractures of ceramic femoral heads resulted from correctable manufacturing and material flaws. Like Hannouche et al. [7], we did not observe this devastating complication after implantation of an alumina head on the old Morse taper. However, there might be different regulations for using ceramic heads on old fixed stems in different countries and depending on different manufacturers. Furthermore, all the stems and Morse taper were made of titanium in this series, and the authors have not experienced use of a new ceramic head on a used Morse taper with cobalt-chromium or stainless steel stems. For these stems, a titanium sleeve [16] has been proposed for use with an alumina head on the old Morse taper. Another solution to change the femoral head could be to use the cement-within-cement technique [13] in isolated cup revision presenting with a stable stem. This technique allows for a better visualization of the acetabulum and prevents Morse taper damage.

In summary, this study demonstrates an isolated cup revision with a new alumina femoral head (in hips that have a stable stem component) is able to halt femoral osteolysis progression (no change or osseous restoration) during a period of 10 years if this osteolysis is less than 1000 mm² (for a 1000-mm² lesion size; Fig. 2A).

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