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Implant wear and osteolysis with a hydroxylapatite-coated screw cup

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Abstract Radiographs of 72 uncemented hip implants with a mean follow-up of 6.5 years were analysed to measure wear of the implant. The wear rate was measured using the modified technique of Livermore and was found to be 0.13 mm per year (CI 95% 0.080–0.18). There was no statistical correlation between wear and age, gender and cup angle, but there was a correlation between wear and the number and size of cysts. This has not been previously published. In view of the risk of loosening and of a dramatic increase in the rate of wear when the femoral head articulates with the metal backing, it is important to plan revision of these cups in good time and to ensure regular radiographic surveillance of these patients.

Résumé Nous avons étudié les radiographies de 72 prothèses de la hanche non-cimentées (Landos, France) pour mesurer l'usure de l'insert acétabulaire. Le suivi moyen était 6,5 années. L'usure a été mesurée avec la technique modifiée de Livermore, comme décrit par Rokkum et Reigstad. L'usure par an était 0,13 mm (CI 95% 0,080–0,18). Aucune corrélation statistique n'a été trouvée entre usure et âge, genre et angle de la cupule. Cependant une corrélation significative a été trouvée entre l'usure et la quantité de kystes acétabulaires. Le haut taux d'usure a déjà été publié avec une tête fémorale différente mais la corrélation statistique entre taux d'usure et formation de kystes ne l'a pas été. À cause du risque

de descellement et d'usure quand le col fémoral entre en contact avec la cage de métal, il est important de suivre ces malades régulièrement et de prévoir une révision dans le temps.

Introduction

Hydroxylapatite (HA)-coated total hip implants have been in use for several years, and although early reports showed promising results [3, 5, 10, 14], longer follow-up revealed the appearance of clinical problems due to wear of the polyethylene acetabular implant [1, 2, 4, 6, 9, 11, 12]. In this study we investigated the polyethylene wear of a hydroxylapatite-coated total hip implant and the concomitant cyst formation that occurs as a result of the associated osteolysis.

Patients and methods

We reviewed the radiographs of 72 primary total hip implants (Landos Corail, Landanger, Chaumont, France) in 64 patients. There were 47 women and 25 men, and their ages ranged between 36 and 79 (mean 62) years. The follow-up period ranged between 22 and 105 (mean 79.25) months. The operations were performed between August 1991 and May 1994. The acetabular component consisted of a hemispherical, self-tapping screw cup made of TiAl_6V_4 with the entire outer surface plasma sprayed with calcium hydroxylapatite (characteristics: thickness $155 \pm 35 \mu\text{m}$, purity greater than 98%, crystallinity between 50–70%, bonding strength 35 MPa). Femoral heads measuring 32 mm were used (BioloX alumina, surface roughness characterised by roughness average (Ra)=0.05 μm), and the straight stem was also made of titanium alloy, of which the upper half had been coated with the same HA as the cup. Cup size varied between 44 mm and 60 mm. Details can be seen in Table S1. The liner had been machined from the base resin GUR 412 (Chirulen, Germany) and had a molecular weight of 4.4 million and a density of 0.934 g/cc. The polyethylene was reported to fulfil the International Standards Organization (ISO) standard 5834/2 and the American Society for Testing and Materials (ASTM) standard F648. The same surgeon operated on all the patients and used an anterolateral approach to the hip.

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Fig. 1 Modified measurement technique according to Rokkum and Reigstad. Polyethylene wear of the acetabular component is calculated with the formula: $1/2d-r$. d =distance between the outer borders of the acetabular component

Measurement technique

For radiological assessment both the first and latest post-operative antero-posterior X-rays of the pelvis were examined. These radiographs, centred over the pubis, were standardised by using the same leg position, film quality, field, target distance, magnification, exposure and developing process. Measurements of the femoral head position were corrected for magnification by comparing the known diameter of the femoral head (32 mm) to the measured diameter on the X-ray.

To measure implant wear, Livermore's technique, modified by Rokkum and Reigstad, was used [7, 11]. Femoral head eccentricity in the metal backing was measured by determining the centre of the femoral head using a template with concentric circles. A line was drawn through the points of intersection of the femoral head and the periphery of the metal backing. Further lines were then drawn at an angle of 90° from this base line through the centre of the femoral head and the outer borders of the metal. The distance between the two outer lines ($=d$) was measured, as well as the distance between the line through the centre of the femoral head and the line at the medial border of the metal backing ($=r$) (Fig. 1). The wear was then calculated using the formula $d/2-r$.

Radiographs were assessed by the same person and, to ensure accuracy, 15 radiographs selected at random were measured twice. Antero-posterior radiographs were used to detect the formation of cysts in different Gruen zones. To determine the lateral cup angle, the angle was measured between lines drawn through the lowest point of the ischial bones and through the intersection of the femoral head and the metal backing.

Statistics

Correlation between variables was analysed with Spearman's two-tailed test. Statistical significance was set for $p < 0.05$. The paired sample t -test was used to analyse the two measurements for intra-observer variability.

Results

Table S1 shows the data of gender, age, follow-up period in months, cup size, wear in millimetres, cup angle and cyst formation for every patient. There was no statistical difference between the two measurements that were made twice. The correlation was 0.816 ($p = 0.22$) and the standard error of the mean was 0.17 mm (SD 0.65 mm). Mean eccentricity at the first post-operative radiograph was 0.33 mm (CI 95%: 0.23–0.43) and at the latest post-operative radiograph was 1.18 mm (CI 95%: 0.94–1.43),

resulting in a mean wear of 0.85 mm (CI 95% 0.60–1.11). This means that the wear per year was 0.13 mm (CI 95% 0.08–0.18). The lateral cup angle was 51.3° (SD 5.17), and no statistically significant correlation was found between wear and age or gender, and cup angle (Spearman's $r = -0.04$, $p = 0.7$). Between the wear and the amount of cysts, however, there was a statistically significant correlation (Spearman's $r = 0.30$, $p = 0.01$).

Discussion

In 1998 Rokkum and Reigstad [11] reported on the amount of wear of a similar screw cup, but this had a different femoral head and stem. In their study 32 mm stainless steel heads of Inox with a surface roughness of $R_a = 0.05 \mu\text{m}$ were used. The straight, tapering stem was entirely plasma-sprayed, giving an HA coating with the same characteristics as used by us. However, in our study a 32-mm femoral head of alumina with the same surface roughness was used. Our femoral stem had a similar design but only was coated at the upper half with a comparable HA coating. The mean eccentricity rate that Rokkum and Reigstad found in 79 hips with a follow-up of 5 years was 0.14 mm (CI 95% 0.11–0.18) per year. These findings are comparable to the 0.13 mm (CI 95% 0.08–0.18) annual wear rate found in our series. However, we found a mean femoral-head eccentricity on the first post-operative radiograph of 0.33 mm (CI 95% 0.23–0.43) compared to an eccentricity of 0.15 mm (CI 95% 0.09–0.20) in their study. But this difference does not influence the final outcome, as the calculations have been made in a similar way and the wear direction could not be assessed because of the metal backing's irregular outer surface.

Livermore et al. [7] developed a technique to determine acetabular component wear and following 385 hips for at least 9.5 years. They found a maximum of wear directed at 15° medial to a vertical line. Based on this work [7], we estimated that the true wear may be twice as high as the wear measured in the present study, and this agrees with the comments of Rokkum et al. [11]. According to the conclusions of Livermore et al. [7], the true wear is approximately 0.26 mm per year.

Bankston et al. [1] found linear wear rates of 0.06 mm per year, 0.05 mm per year and 0.08 mm per year for stainless steel, cobalt chrome, and titanium alloy bearing surfaces respectively. Their results showed linear wear rates of 0.011 mm per year in a metal-backed group and 0.08 mm per year in a non-metal-backed group.

Both the method of polyethylene fabrication and the use of a metal backing have a significant effect on the wear rate in contrast with a metal femoral bearing, which has minimal (if any) effect. Sychterz et al. [14] found, in different "retrieved" polyethylene liners, a mean wear rate of 0.07 mm per year. They found significantly higher wear rates of press-fit, metal-backed liners compared to all-polyethylene cemented cups. Chen et al. [2] found, in an in vitro test of five models from four manufacturers

Fig. 2 **a** Radiograph pelvic 10 years after implantation. Because of the extreme polyethylene wear, the right femoral head articulates against the radiographic orientation ring and the metal of the screw cup. A large bone cyst is located behind the screw cup. On the contralateral side a revision was previously performed. **b** Polyethylene insert of the same patient, removed during revision. On one side (see arrow) the polyethylene is completely worn out

with different locking mechanisms, that a stable locking mechanism and a smooth acetabular shell surface are important in minimising polyethylene liner wear. Xenos et al. [15] found greater liner wear of porous-coated anatomic total hip arthroplasties for patients with osteolysis, but this relation was not statistically significant. Nashed et al. [9] found the highest statistically significant osteolysis rate with fixed titanium heads and cementless Biologic ingrowth anatomic system cups, and the lowest osteolysis rate with fixed titanium heads and cemented polyethylene cups. Devane et al. [4] also found significantly greater volumetric polyethylene wear in cementless titanium metal-backed Mallory-head prostheses than in cemented cups. However, they only found osteolysis

to be associated with an increased polyethylene wear rate in cemented prostheses. Sochart et al. [13] found in Charnley low-friction arthroplasties significant relations between the prevalence of osteolysis and component loosening. Livermore et al. [7] found in cemented polyethylene cups a significant increase of polyethylene wear with 32-mm heads when compared to 28-mm heads.

It is known that “third body” wear of HA particles can be responsible for increased polyethylene wear [8]. Lai et al. [6] described a negative correlation between the residual HA coating on loose cups and the duration of implantation of the same prosthesis as we used in this study. Therefore, third body wear could very well contribute significantly to the polyethylene wear found in our study.

The significant relation between osteolysis (cyst formation) and polyethylene wear that we found has not previously been described for these cups. This information is important for clinicians and means that these implants need regular radiographic follow-up. Because of the risk of loosening and of the dramatic increase of wear rate when the femoral head articulates with the metal backing, it is important to plan adequately early revision of these cups (Figs 2a and 2b). The actual surgery indicated depends on the clinical situation, and when the cup is loose a complete revision should be performed. Usually, we use impaction grafting of donor bone to fill any bone loss, followed by cement fixation of a new polyethylene cup. When the fixation of the original cup is satisfactory but cysts have appeared, then these can be filled with donor bone—or artificial materials such as HA and tricalcium phosphate (TCP) granules or paste—introduced through the holes in the cup. This is followed by insertion of a new liner. The polyethylene liner thickness can then be significantly increased by replacing the 32-mm femoral head by a 28-mm femoral head. Whether this rationale gives better results than complete cup revision has yet to be proved by further prospective studies.

References

1. Bankston AB, Cates H, Ritter MA, Keating EM, Faris PM (1995) Polyethylene wear in total hip arthroplasty. *Clin Orthop* 317:7–13
2. Chen PC, Mead EH, Pinto JG, Colwell CW Jr (1995) Polyethylene wear debris in modular acetabular prostheses. *Clin Orthop* 317:44–56
3. D’Antonio JA, Capello WN, Jaffe WL (1992) Hydroxylapatite-coated hip implants. Multicenter three-year clinical and roentgenographic results. *Clin Orthop* 285:102–115
4. Devane PA, Robinson EJ, Bourne RB, Rorabeck CH, Nayak NN, Horne JG (1997) Measurement of polyethylene wear in acetabular components inserted with and without cement. A randomized trial. *J Bone Joint Surg [Am]* 79:682–689
5. Geesink RG, Hoefnagels NH (1995) Six-year results of hydroxyapatite-coated total hip replacement. *J Bone Joint Surg [Br]* 77:534–547
6. Lai KA, Shen WJ, Chen CH, Yang CY, Hu WP, Chang GL (2002) Failure of hydroxyapatite-coated acetabular cups. Ten-year follow-up of 85 Landos Atoll arthroplasties. *J Bone Joint Surg [Br]* 84:641–646

7. Livermore J, Ilstrup D, Morrey B (1990) Effect of femoral head size on wear of the polyethylene acetabular component. *J Bone Joint Surg [Am]* 72:518–528
8. Morscher EW, Hefti A, Aebi U (1998) Severe osteolysis after third-body wear due to hydroxyapatite particles from acetabular cup coating. *J Bone Joint Surg [Br]* 80:267–272
9. Nashed RS, Becker DA, Gustilo RB (1995) Are cementless acetabular components the cause of excess wear and osteolysis in total hip arthroplasty? *Clin Orthop* 317:19–28
10. Oosterbos CJ, Rahmy AI, Tonino AJ (2001) Hydroxyapatite coated hip prosthesis followed up for 5 Years. *Int Orthop* 25:17–21
11. Rokkum M, Reigstad A (1998) Polyethylene wear with an entirely HA-coated total hip replacement: 79 hips followed for 5 years. *Acta Orthop Scand* 69:253–258
12. Rossi P, Sibelli P, Fumero S, Crua E (1995) Short-term results of hydroxyapatite-coated primary total hip arthroplasty. *Clin Orthop* 310:98–102
13. Sochart DH (1999) Relationship of acetabular wear to osteolysis and loosening in total hip arthroplasty. *Clin Orthop* 363:135–150
14. Sychterz CJ, Moon KH, Hashimoto Y, Terefenko KM, Engh CA Jr, Bauer TW (1996) Wear of polyethylene cups in total hip arthroplasty. A study of specimens retrieved post mortem. *J Bone Joint Surg [Am]* 78:1193–1200
15. Xenos JS, Hopkinson WJ, Callaghan JJ, Heekin R, Savory CG (1995) Osteolysis around an uncemented cobalt chrome total hip arthroplasty. *Clin Orthop* 317:29–36