Early Follow-up for a Hybrid Total Hip Arthroplasty Using a Metal-Backed Acetabular Component Designed to Reduce “Backside” Polyethylene Wear

Colin E. Poole, MD · Shantanu S. Patil, MD · Darryl D. D’Lima, MD · Clifford W. Colwell, Jr., MD

© Hospital for Special Surgery 2005

Abstract Modular acetabular systems have several advantages; however, increased polyethylene wear has been recognized as a disadvantage. In our study, an acetabular shell design with a highly polished inner surface, a locking mechanism that minimizes micromotion, and a high polyethylene liner to shell conformity was evaluated. A prospective cohort of 50 consecutive hips was followed up for a mean of 3.6 years (range, 2–7 years). One patient required an early revision for recurrent instability. Mean linear head penetration rates were 0.242 mm/year (range, 0.048–0.655 mm/year). The true linear wear rate was calculated after subtracting the linear wear in the first follow-up year from the total wear at the end of the follow-up. The true linear wear rate was 0.173 mm/year (range, 0.03–0.423 mm/year). A positive correlation was found between wear rate and male gender. The low head penetration rates suggest that a polished liner with an improved locking mechanism and increased liner conformity can reduce polyethylene wear.

Key words total hip arthroplasty · polyethylene wear · backside wear · clinical outcomes · radiographic outcomes

Introduction

The issue of wear of ultra-high molecular weight polyethylene bearing surfaces has become a dominant theme in hip arthroplasty. A consensus has emerged that aseptic osteolysis is a cell-mediated process driven by the presence of wear debris particles (predominantly polyethylene) and is one of the most common causes for failure of total hip arthroplasty. The advantages of modular acetabular systems with a metal shell and a removable polyethylene

insert over cemented polyethylene components are questionable when polyethylene wear rates are compared. Average wear rates of cemented all-polyethylene acetabular components were reported to be between 0.07 and 0.15 mm/year [5, 14, 25]. In contrast, higher wear rates for cementless acetabular components were reported, some as high as 0.77 mm/year [1, 7]. This would equate to a greater potential for wear debris related to osteolysis in modular systems.

Factors thought to contribute to the increased polyethylene wear rates seen in modular implants are the conformity between the polyethylene liner and the metal shell and problems with the locking mechanism retaining the liner within the shell. Another possible source for increased polyethylene wear is from the nonarticular surface of the liner, so called “backside wear”. A study by Chen et al [6] suggests that a stable locking mechanism and a smooth acetabular shell surface are important in minimizing polyethylene liner wear and polyethylene debris production.

A newer generation of modular acetabular systems was developed to address these concerns. This study measured polyethylene wear rates in patients implanted with a metal-backed acetabular component with a highly polished inner surface, high conformity between liner and shell, and a locking mechanism that minimized micromotion at the interface between the liner and the shell.

Materials and methods

A cohort of 50 consecutive primary total hip arthroplasties performed at Scripps Clinic (La Jolla, CA) between April 1994 and July 1997 were followed up prospectively. The indication for surgery was symptomatic osteoarthritis of the hip refractory to appropriate conservative medical management. All procedures were performed by or under the direct supervision of the senior author (CWC Jr). A modified posterior-lateral approach to the hip was used in

C.E. Poole, MD · S.S. Patil, MD · D.D. D’Lima, MD · C.W. Colwell Jr., MD (✉)
Shiley Center for Orthopaedic Research and Education at Scripps Clinic,
11025 North Torrey Pines Road, Suite 140, La Jolla, CA 92037, USA
e-mail: colwell@scripps.edu

all cases. A titanium alloy, modular, metal-backed, porous-coated, noncemented (Reflection, Smith & Nephew, Memphis, TN, USA) acetabular component was implanted. A cobalt-chrome alloy femoral component (Spectron, Smith & Nephew) was cemented with centrifuged polymethylmethacrylate. A 28-mm cobalt-chrome alloy femoral head was used in all cases. All liners were sterilized in ethylene dioxide.

To obtain the x-rays, patients were placed in a supine position, non-weight-bearing, with their lower limbs internally rotated. Anterior-posterior radiographs of the pelvis were obtained at the initial follow-up (3 months) and at final follow-up visits (range, 2–7 years). For all the radiographs, the x-ray beam was centered over the pubis. Cross-table lateral radiographs of the acetabulum and frog-view lateral radiographs of the upper femur were also obtained. All radiographs were analyzed for subsidence, endosteal lysis, cortical hypertrophy, acetabular abduction angle, implant-bone interface evaluation of the acetabulum, acetabular migration, and head penetration into the liner.

Initial postoperative and long-term follow-up radiographs were digitized using a flatbed scanner (Scanmaker 9600XL, Microtek Inc, Carson, CA, USA) and were analyzed using Polyware Pro 3D (Draftware Developers Inc, Vevay, IN, USA). Polyware Pro 3D measures head penetration in the liner by using an edge-detection algorithm to trace the edges of the head and of the metal shell on the digitized radiograph. By using the angle of projection of the x-ray beam relative to the pelvis, the 3-dimensional position of the head in the acetabular component was reconstructed mathematically [10]. The linear head penetration was measured as the difference in relative head position between 2 sets of radiographs (early follow-up and late follow-up). This method has a reported accuracy of 0.05 mm [11]. Head penetration into the liner represented a combination of polyethylene creep and wear. Volumetric polyethylene wear was the volume of polyethylene calculated to be lost to allow for displacement of the femoral head. Several reports suggest that the major portion of polyethylene creep occurs during the postoperative first year. In those patients who were radiographed at the 1-year follow-up in addition to the final follow-up, the linear head penetration at 1 year was subtracted from the head penetration at final follow-up. Therefore, the head penetration rate between the 1-year and the final follow-up was used as an estimate of the true linear wear rate.

Endosteal osteolysis was defined as lucency at the implant-cement or cement-bone interface on anterior-posterior or lateral radiographs demonstrating cavitation with a minimal longitudinal measurement of 5 mm and a width greater than 3 mm. These measurements were recorded according to location by radiographic zones as described by DeLee and Charnley [9], Gruen et al [15], and Johnston and Crowninshield [18]. Clinical evaluation included Harris hip scores obtained preoperatively and at each postoperative follow-up [17]. The result was classified as excellent (Harris hip score between 90 and 100), good (80–89), fair (70–79), or poor (less than 70). Postoperative thigh pain and the associated inciting level

of activity were classified as: grade 0=no thigh pain, grade 1 (mild)=thigh pain with unusual activities only, grade 2 (moderate)=thigh pain with activities of daily living, and grade 3 (severe)=thigh pain at rest.

Statistical analysis of data was performed using Systat 7.0 (SPSS Inc, Chicago, IL, USA). The effect of various clinical and radiographic factors on the rate of polyethylene wear was examined with the use of the Student *t* test for difference due to gender and with multiple-regression analysis for differences due to age, weight, cup abduction angle, and Harris hip score.

Results

All 46 patients (50 hips) undergoing implantation were accounted for. One patient died of natural causes unrelated to the surgery or anesthetic. Of the remaining 45 patients (49 hips), 43 (46 hips) were examined by the investigators and were radiographed at Scripps Clinic. The other 2 patients (3 hips) were examined by independent physicians. The appropriate radiographs were obtained from these physicians for analysis.

Mean patient age at surgery was 72.2 years (range, 59–84 years); the mean follow-up was 3.6 years (range, 1.4–6.9 years). Preoperative Harris hip scores of 65.6 (range, 34–83) and postoperative scores of 94.9 (range, 85–100) demonstrated significant postoperative improvement in function, pain relief, and motion. Four patients (8.16%) had thigh pain (all grade 1). One hip required early revision (within 3 months) of the acetabulum for recurrent instability. To achieve stability, the acetabular shell was repositioned and the 28-mm head was exchanged for a 32-mm head with a matching liner.

Mean acetabular shell abduction angle was 44.9° (range, 34.2–57.4°). No radiographic evidence of endosteal osteolysis or evidence of femoral or acetabular component migration was found. Radiographic analysis of head penetration into the liner measured a combination of creep and wear. Mean linear head penetration rate was 0.24 mm/year (range, 0.05–0.66 mm/year). This yielded a mean calculated volumetric wear rate of 114.85 mm³/year. No correlation was found between patient demographics, such as age, gender, or weight, and head penetration rate or volumetric wear rate. No correlation was found between clinical outcome measures (Harris hip score or thigh pain) and head penetration rate.

The head penetration rate between the 1-year and the final follow-up was used as an estimate of the true linear wear rate. In those patients, the true linear wear rate was 0.173±0.136 mm/year. A higher mean true linear wear rate was measured in hips of male patients (0.22±0.13 mm/year) compared with hips of female patients (0.12±0.13 mm/year, *p*=0.048).

Discussion

The pathophysiology of aseptic osteolysis and of subsequent implant failure has been well characterized. Conse-

quently, wear of polyethylene bearing surfaces with the generation of particulate debris has become a dominant issue in orthopedics. Numerous authors demonstrated a significant association between high polyethylene wear rates and premature implant failure. Wear rates for metal-on-polyethylene bearings were reported to be between 0.07 and 0.77 mm/year [1, 4].

There are several advantages of modularity with a metal-backed shell and a removable polyethylene liner. Modular acetabular components facilitate shell positioning intraoperatively, expand the choices for liner designs, and permit the easy exchange of a damaged liner without disturbing the bone-implant interface in a well-fixed acetabular shell. The disadvantages include a relatively higher rate of polyethylene wear compared with cemented nonmodular sockets [7, 26], the possibility for the generation of particulate wear debris at two polyethylene surfaces [6, 12, 19], and the dissociation of the modular polyethylene insert [3, 8, 13, 21, 24].

An area of modularity that has been addressed to reduce polyethylene wear is the roughness of the “backside” articulating surface. Wear studies have shown that rougher counterfaces tend to generate more biologically active micron-sized particles than smooth counterfaces [16]. Congruency between the modular polyethylene and the metal shell, as well as the push-out and lever-out forces of the locking mechanism of the liner into the shell, were associated with contact stresses and with subsurface stresses in polyethylene and subsequent wear debris generation [6, 23].

Chen et al [6] studied 5 different designs and found marked differences in the security of the acetabular shell and the polyethylene liner locking mechanism, wear pattern, damage sites, and the amount of polyethylene debris on the acetabular shell and on the polyethylene liner surfaces. Different wear patterns were seen on image analysis and on scanning electron microscopy. The mean liner backside surface wear area varied widely (between 0.26 and 4.61 cm²) among the different designs. In general, a stable locking mechanism and a smooth acetabular shell surface correlated with lower polyethylene liner wear and with lower polyethylene debris production. Fehring et al [12] reported similar variability in liner-shell micromotion (from 5 to 311 µm) in modular acetabular components from 8 different manufacturers. Lieberman et al [19] also related micromotion to backside surface damage of modular polyethylene liners. Young et al [26] reported a wear rate of 0.11 mm/year in nonmodular acetabular cups, which was lower and was more consistent than the wear rates seen in modular cups (0.16 mm/year).

All radiographs were obtained from patients who were placed in a supine, non-weight-bearing position. There may be differences between the head penetration measured on weight-bearing radiographs and that measured on supine radiographs. However, two recent studies [20, 22] have shown no significant differences between wear rates calculated from weight-bearing and from non-weight-bearing radiographs during the first 2 to 3 years of follow-up. However, later follow-up should include both

weight-bearing and non-weight-bearing radiographs to calculate wear rates.

This study indicated that a modular acetabular system incorporating the design features of a locking mechanism that minimizes liner micromotion, and a high liner-shell congruency can result in polyethylene wear rates in the lower range of reported wear rates. This early observed overall head penetration rate was slightly higher than the reported wear rates of cemented acetabular components but was much lower than the reported wear rates for non-cemented acetabular components [1, 7]. To account for the creep and running in of the polyethylene liner, which takes place in the initial period, the true linear wear rate was also estimated. The true linear wear rate (head penetration rate after the first year of follow-up) was significantly lower than the overall head penetration rate. A longer-term follow-up of this cohort is essential to determine the significance of these promising early findings.

References

1. Bono JV, Stanford L, Toussaint JT (1994) Severe polyethylene wear in total hip arthroplasty. Observations from retrieved AML PLUS hip implants with an ACS polyethylene liner. *J Arthroplasty* 9:119–125
2. Brooker AF, Bowerman JW, Robinson RA, Riley LH (1973) Ectopic ossification following total hip replacement. *J Bone Joint Surg Am* 55:1629–1632
3. Bueche MJ, Herzenberg JE, Stubbs BT (1989) Dissociation of a metal-backed polyethylene acetabular component. A case report. *J Arthroplasty* 4:39–41
4. Callaghan JJ, Pedersen DR, Olejniczak JP, Goetz DD, Johnston RC (1995) Radiographic measurement of wear in 5 cohorts of patients observed for 5 to 22 years. *Clin Orthop* 317:14–18
5. Charnley J, Halley DK (1975) Rate of wear in total hip replacement. *Clin Orthop* 112:170–179
6. Chen PC, Mead EH, Pinto JG, Colwell CW Jr (1995) Polyethylene wear debris in modular acetabular prostheses. *Clin Orthop* 317:44–56
7. Chmell MJ, Rispler D, Poss R (1995) The impact of modularity in total hip arthroplasty. *Clin Orthop* 319:77–84
8. de Kleuver M, Kooijman MA, Pavlov PW, Veth RP (1997) Triple osteotomy of the pelvis for acetabular dysplasia: Results at 8 to 15 years. *J Bone Joint Surg Br* 79:225–229
9. DeLee JG, Charnley JG (1976) Radiological demarcation of cemented sockets in total hip replacement. *Clin Orthop* 121:20–32
10. Devane PA, Bourne RB, Rorabeck CH, Hardie RM, Horne JG (1995) Measurement of polyethylene wear in metal-backed acetabular cups. I. Three-dimensional technique. *Clin Orthop* 319:303–316
11. Devane PA, Bourne RB, Rorabeck CH, MacDonald S, Robinson EJ (1995) Measurement of polyethylene wear in metal-backed acetabular cups. II. Clinical application. *Clin Orthop* 319:317–326
12. Fehring TK, Smith SE, Braun ER, Mobley C, Wang PL, Griffin WL (1999) Motion at the modular acetabular shell and liner interface. A comparative study. *Clin Orthop* 367:306–314
13. Gonzalez DV, Ruzo PS, Li S, Pellicci P, Sculco TP, Salvati EA (2001) Dislodgment of polyethylene liners in first and second-generation Harris-Galante acetabular components. A report of eighteen cases. *J Bone Joint Surg Am* 83:553–559
14. Griffith MJ, Seidenstein MK, Williams D, Charnley J (1978) Socket wear in Charnley low friction arthroplasty of the hip. *Clin Orthop* 137:37–47
15. Grueh TA, McNiece GM, Amstutz HC (1979) “Modes of

- failure” of cemented stem-type femoral components. *Clin Orthop* 141:17–27
16. Hailey JL, Ingham E, Stone M, Wroblewski BM, Fisher J (1996) Ultra-high molecular weight polyethylene wear debris generated in vivo and in laboratory tests; the influence of counterface roughness. *Proc Inst Mech Eng [H]* 210:3–10
 17. Harris WH (1969) Traumatic arthritis of the hip after dislocation and acetabular fractures: Treatment by mold arthroplasty. An end-result study using a new method of result evaluation. *J Bone Joint Surg Am* 51:737–755
 18. Johnston RC, Crowninshield RD (1983) Roentgenologic results of total hip arthroplasty. A ten-year follow-up study. *Clin Orthop* 181:92–98
 19. Lieberman JR, Kay RM, Hamlet WP, Park SH, Kabo JM (1996) Wear of the polyethylene liner-metallic shell interface in modular acetabular components. An in vitro analysis. *J Arthroplasty* 11:602–608
 20. Moore KD, Barrack RL, Sychterz CJ, Sawhney J, Yang AM, Engh CA (2000) The effect of weight-bearing on the radiographic measurement of the position of the femoral head after total hip arthroplasty. *J Bone Joint Surg Am* 82:62–69
 21. O’Brien RF, Chess D (1992) Late disassembly of a modular acetabular component. A case report. *J Arthroplasty* 7 Suppl:453–455
 22. Smith PN, Ling RS, Taylor R (1999) The influence of weight-bearing on the measurement of polyethylene wear in THA. *J Bone Joint Surg Br* 81:259–265
 23. Tradonsky S, Postak PD, Froimson AI, Greenwald AS (1993) A comparison of the disassociation strength of modular acetabular components. *Clin Orthop* 296:154–160
 24. Werle J, Goodman S, Schurman D, Lannin J (2002) Polyethylene liner dissociation in Harris-Galante acetabular components: a report of 7 cases. *J Arthroplasty* 17:78–81
 25. Wroblewski BM (1985) Direction and rate of socket wear in Charnley low-friction arthroplasty. *J Bone Joint Surg Br* 67:757–761
 26. Young AM, Sychterz CJ, Hopper RH Jr, Engh CA (2002) Effect of acetabular modularity on polyethylene wear and osteolysis in total hip arthroplasty. *J Bone Joint Surg Am* 84:58–63