Acetabular Polyethylene Wear and Acetabular Inclination and Femoral Offset

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Abstract Restoration of femoral offset and acetabular inclination may have an effect on polyethylene (PE) wear in THA. We therefore assessed the effect of femoral offset and acetabular inclination (angle) on acetabular conventional (not highly cross-linked) PE wear in uncemented THA. We prospectively followed 43 uncemented THAs for a minimum of 49 months (mean, 64 months; range, 49–88 months). Radiographs were assessed for femoral offset, acetabular inclination, and conventional PE wear. The mean ($\pm$ standard deviation) linear wear rate in all THAs was 0.14 mm/year ($\pm$ 0.01 mm/year) and the mean volumetric wear rate was 53.1 mm³/year ($\pm$ 5.5 mm³/year). In

THAs with an acetabular angle less than 45°, the mean wear was 0.12 mm/year ($\pm$ 0.01 mm/year) compared with 0.18 mm/year ($\pm$ 0.02 mm/year) in those with a reconstructed acetabular angle greater than 45°. Reproduction of a reconstructed femoral offset to within 5 mm of the native femoral offset was associated with a reduction in conventional PE wear (0.12 mm/year versus 0.16 mm/year). Careful placement of the acetabular component to ensure an acetabular angle less than 45° in the reconstructed hip allows for reduced conventional PE wear.

Level of Evidence: Level II, prospective study. See Guidelines for Authors for a complete description of levels of evidence.

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Each author certifies that his or her institution has approved or waived approval for the human protocol for this investigation, that all investigations were conducted in conformity with ethical principles of research, and that informed consent for participation in the study was obtained.

This work was performed at University of Western Ontario.

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Introduction

Aseptic loosening is the most common cause of failure in THA [14]. Conventional PE wear and production of PE debris are recognized as the primary causes of aseptic loosening [3, 4, 11, 13]. PE wear is a multifactorial problem and is influenced by patient, material, and surgical factors [3]. Patient-related factors include gender, age, activity level, and weight [24]. Femoral head size [7, 17] and the properties and composition of the articulating surfaces (including PE quality and manufacture) have been implicated in PE wear [1–3].

Increased contact stress between the articular surfaces can lead to increased wear and can be reduced by a good surgical technique and accurate component positioning [4]. The process of soft tissue balancing of the hip during THA is performed to restore offset and leg length in the reconstructed hip. Femoral offset is most simply stated as the distance between the center of the femoral head and a line drawn through the center of the femoral shaft on a frontal

projection with the hips internally rotated 15° to correct for femoral anteversion. Reconstruction of the leg length and femoral offset can be estimated by using preoperative templating and confirmed intraoperatively using a leg-length offset guide and intraoperative tests including the chuck and drop kick test [3]. Correct acetabular orientation also reduces contact stresses [22]. However, the literature to date has been equivocal on the effect of offset and acetabular orientation on linear and volumetric wear [4, 5, 10, 12, 23].

We hypothesized acetabular inclination greater than 45° increases conventional (not highly cross-linked) PE linear and volumetric wear and that restoration of femoral offset to greater or less than 5 mm from native femoral offset increases conventional PE wear.

Materials and Methods

We prospectively followed 43 patients who between 1994 and 1995 underwent THA using an uncemented Mallory-Head® tapered femoral stem (Biomet, Inc, Warsaw, IN), RingLoc® titanium porous plasma-sprayed acetabular shell (Biomet), and ram-extruded ultrahigh-molecular-weight polyethylene (UHMWPE) liner (Hoechst GUR® 4150 HP) gamma irradiated in argon. All patients received a 26-mm cobalt-chrome femoral head (Biomet). All patients presenting to our tertiary referral center with unilateral hip arthritis and subsequently listed for THA were considered for enrollment in the study. We excluded patients with evidence of Perthes' disease, a contralateral THA, or a diseased contralateral hip. To address the hypotheses, the patients were placed in two separate

groups for acetabular inclination (patients with an acetabular inclination less than 45° [n = 25] and patients with an acetabular inclination angle of 45° or greater [n = 18]), and offset (patients with a reconstructed femoral offset within 5 mm of native femoral offset [n = 23] and patients with an offset greater than 5 mm from the native offset [n = 20]) (Fig. 1). The key variables were acetabular inclination, restoration of femoral offset, linear wear per year, and volumetric wear per year. We estimated a sample size of 18 in each group was needed to provide a power of 80% to detect a clinically meaningful difference of 50% (0.05 mm/year; standard deviation, 0.06) in linear wear rate at alpha = 0.05.

The THA was performed through the direct lateral approach and performed or supervised by the senior authors (CRB, RBB). The acetabular component was press fit with the acetabular cup 1 mm larger than the reamed diameter. All liners were placed to allow the metal ring in the outer shell periphery to seat securely into the machined groove of the UHMWPE liner.

All patients had immediate postoperative anteroposterior (AP) and lateral radiographs of the hip. We took repeat radiographs yearly until the latest followup. No patients were lost to followup. The minimum followup was 49 months (mean, 64 months; range, 49–88 months). AP radiographs were taken with the legs positioned in 15° internal rotation with the coccyx centered 2 cm above the pubic symphysis. Three of us (JAG, CAB, JM) measured all radiographs for native and reconstructed femoral offset, acetabular inclination, and acetabular anteversion from the standardized radiographs using MATLAB® (The MathWorks Inc, Natick, MA). Any interobserver difference between measurements was noted and remeasured.

Fig. 1 A flowchart shows the acetabular and femoral offset groups.

Fig. 2 An image of a Mallory-Head[®] femoral prosthesis and RingLoc[®] acetabular component show measurement of native and reconstructed femoral offset and acetabular inclination. Reconstructed femoral offset (a) was measured as the distance from the center of rotation of the femoral head (b) to the long axis of the femoral shaft (c). We repeated measurements on the disease-free contralateral hip (d). Acetabular inclination (abduction) was measured by drawing a horizontal line joining the inferior border of the inferior pubic rami (e). The acetabular inclination angle (g) was subtended by a second line drawn parallel to the opening plane of the acetabular component (f) and the horizontal reference line.

Reconstructed femoral offset (Fig. 2a) was measured as the distance from the center of rotation of the femoral head (b) to the long axis of the femoral shaft (c). We repeated measurements on the disease-free contralateral hip (d). Acetabular inclination (abduction) was measured using the AP radiograph. A horizontal line was drawn joining the inferior border of the inferior pubic rami (e). The acetabular inclination angle (g) was subtended by a second line drawn parallel to the opening plane of the acetabular component (f) and the horizontal reference line. Acetabular inclination was measured from the shoot-through direct lateral radiograph. The radiographic plate was oriented parallel to the floor and anteversion or retroversion measured in terms of the number of degrees of forward or backward tilt from the perpendicular.

We analyzed linear and volumetric wear using the three-dimensional method described by Martell and Berdia [18]. This computer-assisted vector wear analysis program has shown superior repeatability and accuracy in comparison with manual techniques. The method is based on digitized radiographs and uses image analysis to fit best-matched circles to the femoral head and acetabulum. Also, it does not assume the center of the prosthetic head coincides with that of the acetabular metal shell.

For all 43 patients, the mean normal hip offset was 36.5 mm and the mean offset at followup was 34.4 mm. The mean acetabular inclination (abduction) postoperatively was 42.3° and mean anteversion of the acetabular

Table 1. Comparison of study group variables

Variable	Value
Number of patients	43
Followup (months)	64.6 (61.6–67.6)
Nonoperated hip offset (mm)	36.4 (33.9–39.0)
THA offset (mm)	34.3 (32.2–36.5)
Acetabular inclination (degrees)	42.3 (40.3–44.3)
Acetabular anteversion (degrees)	12.7 (10.2–15.2)
Linear wear rate (mm/year)	0.14 (0.11–0.17)
Volumetric wear rate (mm ³ /year)	53.1 (42.0–64.1)

Values are expressed as means, with 95% confidence intervals in parentheses.

Fig. 3 A bar chart shows increased wear with an acetabular inclination greater than 45°.

component was 12.7°. The mean linear wear rate was 0.14 mm/year and the mean volumetric wear rate was 53.1 mm³/year (Table 1).

Data were analyzed for distribution using the Kolmogorov-Smirnov test and were normally distributed. The dependent variables were linear and volumetric wear. Independent variables were age, length of followup, acetabular inclination, femoral offset, and acetabular component version. We determined differences in linear and volumetric wear between patients with acetabular inclinations greater than 45° and patients with acetabular inclinations less than 45° using the unpaired Student's *t* test. We determined differences in linear and volumetric wear between patients with restoration of femoral offset to within 5 mm of native offset and patients with restoration of femoral offset to greater than 5 mm of native offset using the unpaired Student's *t* test. Statistical analysis was performed using SPSS[®] 12.0 (SPSS Inc, Chicago, IL).

Results

The linear wear rate was lower ($p = 0.012$) in the group in which the acetabular inclination was less than 45° (0.12 versus 0.18 mm/year) (Fig. 3; Table 2). Furthermore, the

Table 2. Comparison of variables and wear rates

Variable	Group 1 (inclination < 45°)	Group 2 (inclination > 45°)	p Value
Number of patients	25	18	
Age (years)	65.2 (60.7–69.6)	58.9 (52.7–65)	
Followup (months)	65.2 (61.2–69.0)	63.8 (59.2–68.3)	
Change in offset (mm)	−2.0 (−4.6–0.7)	−3.3 (−6.2 to −0.3)	
Acetabular anteversion (degrees)	12.6 (9.0–16.3)	12.4 (9.0–15.7)	
Linear wear rate (mm/year)	0.12 (0.09–0.14)	0.18 (0.13–0.23)	0.012
Volumetric wear rate (mm ³ /year)	45.4 (35.4–55.3)	65.63 (44.1–87.2)	0.068

Values are expressed as means, with 95% confidence intervals in parentheses.

volumetric wear rate was lower ($p = 0.068$) in the group in which the acetabular inclination was less than 45° (45.36 versus 65.63 mm³/year) (Table 2).

The linear wear rate was lower ($p = 0.094$) in patients with a postoperative offset reproduced to within 5 mm of the normal side (0.12 versus 0.16 mm/year) (Fig. 4; Table 3). The volumetric wear rate was lower ($p = 0.17$) in the group with postoperative offset reproduced to within 5 mm of the normal side (46.8 versus 61.9 mm³/year) (Table 3).

Fig. 4 A bar chart shows increased wear with restoration of the femoral offset within greater than 5 mm of the native femoral offset.

Discussion

Correct orientation of the acetabular component is an important factor in THA survival. Malpositioned acetabular components may result in dislocation, impingement, reduced range of motion, and increased PE wear. Orientation of the positioned cup is typically 45° relative to the horizontal plane and 20° anteverted [16, 20]. However, the literature is equivocal regarding the exact effect of acetabular orientation on PE wear [5, 12, 15, 21]. A failure to reproduce femoral offset in THA can result in limp, fatigue, impingement, and recurrent subluxation and dislocation [3]. It may result in increased joint reaction forces and PE wear [6]. The questions from this study are: (1) does a THA with an acetabular inclination angle greater than 45° increase linear and volumetric UHMWPE wear, and (2) does a THA with a femoral offset greater than 5 mm of native femoral offset increase linear and volumetric UHMWPE wear.

There are some limitations to this study. First, many factors influence UHMWPE wear. In this study, there were no differences between age, femoral head size, length of followup, or femoral anteversion in the different groups. However, patient gender, weight, and activity level can influence UHMWPE wear [24], and these variables were not measured. Second, we calculated the power analysis to

Table 3. Comparison of variables and wear rates

Variable	Group 1 (offset ≤ 5 mm of normal)	Group 2 (offset > 5 mm of normal)	p Value
Number	23	20	
Age (years)	63.6 (58.3–69.0)	61.3 (56.0–66.5)	
Followup (months)	63.3 (59.3–67.3)	66.1 (61.7–70.4)	
Acetabular inclination (degrees)	40.85 (38.5–43.2)	43.99 (40.8–47.2)	
Acetabular anteversion (degrees)	11.8 (7.9–15.6)	13.4 (10.2–16.5)	
Linear wear rate (mm/year)	0.12 (0.09–0.15)	0.16 (0.12–0.20)	0.09
Volumetric wear rate (mm ³ /year)	46.8 (34.4–59.2)	61.9 (43.3–80.5)	0.17

Values are expressed as means, with 95% confidence intervals in parentheses.

answer the question of the effect of acetabular inclination greater than 45° on UHMWPE wear. Recalculating this power analysis for the femoral offset hypothesis, using the means and standard deviations from these data, shows 50 patients in each group would be needed to give 80% chance of refuting the null hypothesis. Third, wear measurement techniques cannot differentiate between bedding-in and true PE wear [19]. Head penetration during the first 6 months is creep-dominated, but after 1 year, all penetration is attribution to wear [9]. Wear rates taken at 5 years followup therefore may be artificially high owing to the bedding-in of uncemented acetabular components and a longer followup may be beneficial to reduce this effect. This study, however, shows an average overall linear wear rate of 0.14 mm/year, which lies within an acceptable range reported in previous studies of uncemented THA [8, 23].

With a mean followup greater than 60 months, we found acetabular component abduction of 45° or greater was associated with a 50% increase in linear wear per year compared with an abduction angle less than 45°. There was also a 44% increase in volumetric wear with an acetabular abduction angle greater than 45°. An increase in the acetabular inclination angle (abduction) can lead to an increase in contact stress at the superior aspect of the PE liner, which increases PE wear and debris [21]. This is in contrast to studies by Kligman et al. [15], Goosen et al. [10], and Del Schutte et al. [5], who observed no correlation between PE wear and acetabular component inclination at 5, 8, and 9.5 years, respectively. However, Hirakawa et al. [12] suggested an increase in acetabular component angle greater than 45° leads to an increase in subsequent mechanical failure. Furthermore, Patil et al. [21] examined the effect of acetabular abduction on PE wear using finite element analysis, hip wear simulators, and a clinical followup of 56 patients undergoing 60 THAs at 5 years. They described a theoretical increase in contact stresses and PE wear with an acetabular abduction angle greater than 45°. Furthermore, they noted a 40% increase in linear wear rates with an abduction angle of 45° or greater [21]. However, their patient groups were not matched for femoral offset.

Our study did not show strong evidence that failure to restore the femoral offset to within 5 mm of the normal native hip offset increases linear and volumetric PE wear. This is probably attributable to this arm of the study being underpowered. Despite this, our study does suggest failing to restore the femoral offset to within 5 mm of normal native hip offset is associated with a 33% increase in linear UHMWPE wear and 32% increase in volumetric UHMWPE wear. This finding is supported by previous studies [6, 23]. Sakalkale et al. [23] investigated the effects of increasing femoral offset on PE wear at a mean followup of 5.7 years. Seventeen patients underwent staged bilateral

uncemented THAs. Implants used were similar except for femoral offset. The THA with the greater offset had a 100% reduction in linear wear rates [23]. However, the study compared wear between two THAs and not restoration of normal hip offset on polyethylene wear. Devane and Horne [6] studied the factors affecting PE wear in THA. They compared the ability of two different THAs to restore normal femoral offset. They then compared PE wear in the two groups. In the implant that restored femoral offset to within 1 mm of normal, there was no correlation between offset and wear. In the implant that reduced native femoral offset by an average of 7 mm, they observed a strong correlation between reducing femoral offset in the reconstructed THA and increased PE wear. They concluded underrestoration of femoral offset leads to an increase in PE wear [6].

This study supports previous studies that a reconstructed acetabular inclination greater than 45° considerably increases conventional (not highly cross-linked) UHMWPE wear. Furthermore, failure to reproduce the reconstructed femoral offset to within 5 mm of the native hip may lead to an increase in conventional UHMWPE wear.

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