

Effect of femoral head size on polyethylene wear and synovitis after total hip arthroplasty

A sonographic and radiographic study of 39 patients

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Background and purpose The role of synovitis and high fluid pressure in the loosening process after total hip arthroplasty has gained increasing attention. We investigated the correlation between head size, polyethylene wear, and capsular distention.

Patients and methods We analyzed 39 unrevised, radiographically stable hips that had been operated with 28 or 32 mm femoral heads 10 years earlier because of osteoarthritis. We evaluated radiographic signs of loosening, linear and volumetric polyethylene wear, body mass index, activity level, and age. Sonographic examination was performed to measure capsular distance i.e. the distance between the prosthetic femoral neck and the anterior capsule.

Results Linear wear was 0.09 mm/year and 0.18 mm/year in the 28 mm and 32 mm groups, respectively ($p < 0.001$). The volumetric wear was 51 mm³/year and 136 mm³/year ($p < 0.001$) and the capsular distance was 13 mm and 17 mm, respectively ($p < 0.001$). There was a correlation between linear wear ($r = 0.54$), volumetric wear ($r = 0.62$), and capsular distance ($p < 0.001$).

Interpretation Wear was greater for the larger femoral head and was correlated to capsular distension.

A larger femoral head diameter has been associated with increased polyethylene (PE) volumetric wear (Kesteris et al. 1996, Clarke et al. 1997, Jasty et al. 1997). It has also been suggested that induction of foreign body reaction by PE particles

and subsequent osteolysis is one of the factors that causes aseptic loosening and eventually implant failure after total hip arthroplasty (THA) (Murray et al. 1990, Glant et al. 1993).

It is still poorly understood how PE wear debris influences the prosthetic joint. Howie et al. (1988) presented an animal study in which PE particles alone were found to cause bone resorption in the absence of motion or infection, but later studies did not confirm these results (Howie et al. 1993, Van Der Vis et al. 1997). Thus, PE particles may not be the main cause of osteolysis.

Schmalzried et al. (1992) presented the term “effective joint space”, describing joint fluid distribution, migration, and transportation of PE wear debris in THA. Other factors that are more directly associated with mechanical load and the quality of the interface (Manley et al. 2002) may also be involved in the development of osteolysis. One of these factors may be the increased static and dynamic fluid pressure in the prosthetic hip joint (Robertsson et al. 1997, Aspenberg 1998, Walter et al. 2004). A correlation between loosening and “capsular distension”—i.e. the sonographically measured distance between the prosthetic femoral neck and the anterior capsule of the hip joint—has been reported (Robertsson et al. 1997, Kesteris et al. 1999). Robertsson et al. (1997) also found a correlation between sonographically measured “capsular distension” and intracapsular pressure.

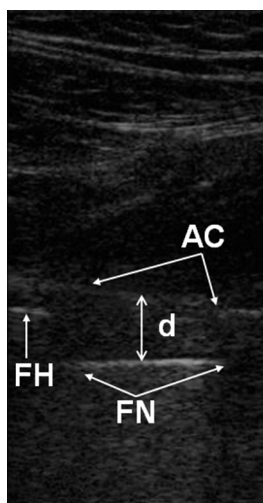


Figure 1. Sonographic measurement of the capsular distance in THA. AC: echo from the anterior surface of the anterior hip joint capsule; FN: echo from the anterior surface of the prosthetic femoral neck; FH: echo from the anterior surface of the prosthetic femoral head; *d* represents the distance between the anterior capsule and the prosthetic femoral neck.

We studied patients with no or minor clinical or radiographic signs of loosening 10–11 years after THA. The aim was to investigate whether there was a correlation between linear/volumetric wear, for 2 head sizes, and age, sex, activity level, or “capsular distension”, i.e. increased synovia and/or increased synovial edema.

Patients and methods

60 unrevised THA patients, operated for OA 1995 and 1996 using 32 or 28 mm femoral heads, were randomly selected and called for review. The same cemented ScanHip stem and all-polyethylene cemented ScanHip cup (Kesteris et al. 1996) had been used in all the patients, but with different head sizes. CMW1 bone cement was used in all cases. The all-polyethylene cup was made of machined, ultra-high molecular weight polyethylene, sterilized in ethylene oxide.

The THAs had been performed by 2 orthopedic surgeons. At the review, all patients had no or only slight pain. A standard anteroposterior pelvic radiograph was taken and 2 of the authors (ST, UK) evaluated them to identify signs of loosening

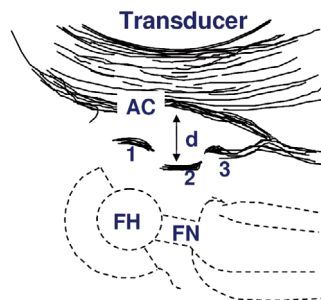


Figure 2. Schematic drawing showing sonographic findings in THA patients. FH: prosthetic femoral head; FN: prosthetic femoral neck; AC: anterior capsule; *d* is the distance between the anterior capsule and the prosthetic femoral neck; 1 is the echo from the prosthetic femoral head (FH); 2 is the echo from the prosthetic femoral neck (FN); 3 is the echo from the prosthetic collar (not always present).

and classify the implant as “loose” or “stable” according to Carlsson et al. (1993). The cup inclination angle was measured and linear PE wear was calculated according to Livermore et al. (1990). The volumetric polyethylene wear was calculated with the formula:

$$V = \frac{r^2 d}{2} \left(\pi + \pi \sin B + \frac{d}{r} \sin(2B) \right)$$

(Ilchmann et al. 2008), in which *V* is volumetric wear, *r* is the radius of the femoral head, *B* is the angle of direction of wear, and *d* is the linear wear.

The sonographic examinations were performed in the sagittal plane, from the anterior aspect of the hip along the axis of the femoral neck. The anterior capsular distance, i.e. the “capsular distension”, was defined as the distance between the metallic echo from the anterior surface of the prosthetic femoral neck and the echo from the anterior surface of the anterior capsule (Figures 1 and 2) (Kesteris et al. 1999, Tarasevicius et al. 2006b). The mean value of 3 measurements of each hip was calculated. UCLA activity assessment was used to classify each patient’s activity level on a 10-point scale (Zahiri et al. 1998).

13 hips were radiographically classified as loose. As shown previously, aseptic loosening is associated with increased capsular distension and wear (Kesteris et al. 1999, 2003). Since we were testing the influence of femoral head diameter on wear and synovitis (capsular distension), we excluded

Data for the 39 THAs, mean (SD)

	28 mm (n = 23)	32 mm (n = 16)	P-value
Linear wear/year, mm	0.09 (0.05)	0.18 (0.09)	< 0.001
Volumetric wear/year, mm ³	51 (28)	136 (70)	< 0.001
Capsular distance, mm	13.1 (2.7)	16.6 (3.0)	< 0.001
Activity level	5.1 (1.2)	5.3 (1.3)	0.7
Age	71 (10)	74 (6.5)	0.2
BMI	30 (5.5)	28 (3.9)	0.3
Cup inclination angle	51 (7.7)	52 (5.4)	0.7
PE wear angle	47 (19)	55 (13)	0.1

the loose hips. We also excluded 4 patients due to technical problems with PE wear measurements, and also the second implanted hip of 4 bilaterally operated patients in order to use patients as the statistical unit. Thus, 39 hips were analyzed, 16 hips implanted in 16 patients in the 32-mm group and 23 hips implanted in 23 patients in the 28-mm group (Table).

Statistics

The primary effect variable, used for power calculation analysis, was capsular distance. With an assumption of a difference in means of 3 mm, and an SD of 3 mm for both groups, and aiming at a power of 0.80 and a risk of 0.05 for type-1 error, 16 patients were required in each group. Age, activity level, capsular distance, and linear and volumetric PE wear were compared between groups using t-test. Multiple regression analysis was used to adjust for possible confounding variables. The Spearman correlation (*r*) was used to calculate the correlation between variables. A *p*-value of < 0.05 was considered significant. SPSS software was used for the calculations.

Results

We found a statistically significant difference in linear and volumetric wear, and also capsular distance between 28-mm and 32-mm heads. Other factors such as activity level, age, cup inclination angle, PE wear direction angle, and BMI values were similar in both groups (Table).

The mean difference between 28-mm and 32-mm groups for linear PE wear was 0.09 mm (95% CI:

0.04–0.13, *p* < 0.001). For volumetric PE wear, the difference was 86 mm³ (95% CI: 53–118, *p* < 0.001) and for the capsular distance it was 3.5 mm (95% CI: 1.6–5.3, *p* < 0.001).

After adjusting for possible confounding variables (BMI, age, PE wear direction, activity level, and cup inclination angle), the mean difference between groups was 0.12 mm (95% CI: 0.07–0.17, *p* < 0.001) for linear PE wear, 104 mm³

(95% CI: 69–140, *p* < 0.001) for volumetric PE wear, and 3.6 mm (95% CI: 1.5–5.7, *p* = 0.002) for capsular distance.

There was a correlation between both linear wear and volumetric PE wear and capsular distance (*r* = 0.54, *p* < 0.001; *r* = 0.62, *p* < 0.001).

No significant correlation was found between cup inclination angle, PE wear direction angle, patient age, activity level, or BMI and PE wear and capsular distance.

Discussion

There are several theories on the causes of aseptic loosening in THA. For several years, the predominant theory was the “particle disease” theory (for review, see Sundfeldt et al. 2006). Another theory, however, that of “increased intracapsular fluid pressure”, describing the effective joint space and its role in the development of aseptic loosening, has been suggested (Robertsson et al. 1997, Aspenberg 1998). We found that THA hips with 32-mm heads had a greater capsular distance than those with 28-mm heads. According to fluid-pressure theory, this sign of capsular expansion may play a role in aseptic loosening because of increased pressure, increased volume of fluid, and the subsequent pumping of joint fluid—which will transport wear debris to the effective joint space where bone cells and macrophages become exposed to it (Manley et al. 2002, Sundfeldt et al. 2006). The finding of greater PE wear in the 32-mm group and the correlation of PE wear with an increased “capsular distension” also suggest that an increased amount of PE particles increases synovitis and/or the volume

of fluid in the THA hip. Thus, PE particles may act as a trigger mechanism to start an inflammatory process in the THA hip, leading to the production of more fluid and increased pressure—as demonstrated by increased capsular distance.

In addition, it has been suggested that increased intracapsular pressure induces osteolytic lesions due to disturbed circulation (Linder 1994), resulting in cysts and subsequent bone loss. This may eventually result in loosening and increased cumulative revision rate (CRR).

Few authors have studied the influence of head diameter on CRR. Marston et al. (1996) followed 413 THA patients for 5–10 years and did not find that survival was affected by head size. Kesteris et al. (1998) followed 1,660 patients for 2–12 years and found no difference between 22-mm and 32-mm heads. However, extended follow-up of the same cohort to 21 years postoperatively revealed that the 32-mm head had a greater revision risk (Tarasevicius et al. 2006a).

We found that there was a correlation between PE wear and capsular distension and head size in THAs with no radiographic signs of loosening. This indicates that the process of increased pressure/capsular distension and subsequent loosening starts before it can be detected radiographically. We cannot claim that the combination of PE particles and high pressure are the main factors that induce aseptic loosening; however, our findings do indicate that they may play a role. It is possible that screening ultrasound would identify risk patients requiring further follow-up. This could save on resources and warrants further studies.

The ScanHip cups used in our study were sterilized in ethylene oxide. Previous studies have shown that ethylene oxide sterilization increases the PE linear wear rate as compared to gamma sterilization in a reduced oxygen environment (Digas et al. 2003, Rohrl et al. 2004). However, there is no evidence in the literature that this increase in PE wear would affect long-term clinical results. The combination of ScanHip stem and ScanHip cup investigated here was described in the Swedish Hip Register and showed a cumulative revision rate of 6.6% (SD 0.9) after 10 years (Malchau et al. 2002). These results suggest that despite increased PE wear in ethylene oxide sterilized cups, the cumulative revision rate remains acceptable 10 years after implantation.

The differences in linear and volumetric wear in the 28-mm and 32-mm groups show that the 28-mm heads resulted in reduced volumetric wear: a difference of about 90 mm³ per year. Previous studies have reported the same reduction in wear rates between groups when comparing 22-mm and 32-mm femoral heads (Livermore et al. 1990, Kesteris et al. 1996). Thus, our findings suggest that the use of 28-mm heads instead of 32-mm heads may reduce the degree of PE wear almost to that of 22-mm heads while avoiding the elevated risk of dislocation with the smallest head. (Berry et al. 2005).

We conclude that compared to 28 mm-heads, 32-mm femoral heads are associated with increased sonographically measured “capsular distension” and increased linear and volumetric wear in radiographically stable THA hips.

Contributions of authors

ST: collection, compilation and analysis of data, and writing of manuscript. UK, RJK: data collection and editing of manuscript. OR: statistical analysis and editing of manuscript. HW: organizing of study and editing of manuscript.

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No competing interests declared

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